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Llywodraeth Cymru
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Principal Inspection Interval Risk Assessment (PIIRA)

Guidance Note and User Manual

Instructions for Use

This guidance document explains the background to the PIIRA process and illustrates where to find the relevant information to undertake the risk assessment.

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1. Introduction

Managing highways structures requires considerable resource. Balancing the need to minimise the risk to public safety and maintaining sufficient data on structures, whilst also ensuring the effective and efficient use of resource is challenging.

CS 450 – Inspection of highway structures is part of the Design Manual for Roads and Bridges (DMRB) and allows for the risk assessment of structures, to extend the Principal Inspection interval from the normal length of 6 years where appropriate. A risk assessment tool and accompanying guidance documents were developed a number of years ago for Welsh Government by Atkins to inform engineering judgment in extending the Principal Inspection interval and to assist with the on-going management of structures to ensure the finite resources available are effectively used. This risk assessment tool has been updated by Welsh Government in conjunction with both North and Mid Wales Trunk Road Agent (NMWTRA) and South Wales Trunk Road Agent (SWTRA). This PAG is based upon the original guidance note and user manual and has been reviewed and updated to correspond with the revised risk assessment tool.

Principal Inspection intervals can be adjusted based on risk assessments. Higher-risk structures typically require six-yearly inspections, while lower-risk structures can have longer intervals. A formal risk assessment process ensures a consistent national approach, documenting engineering judgment with quantifiable results.

The PIIRA pro forma is a simple, quick spreadsheet requiring structural information from the Inspection Pro-Forma and Form Roads 277. It assists but does not replace engineering judgment.

This PAG comprises a Guidance Note and User Manual that explains the risk assessment background and how it informs engineering judgment. It includes illustrations and advice on using the Inspection Pro-Forma and Form Roads 277 for risk assessments.

2. Terms and Definitions

Term	Definition
Critical Bridge Condition Index, BCI_{crit}	The lowest critical bridge condition index score for any of the spans.
New Structure	A structure is considered new when its age is less than or equal to 5% of its design life.
Roads 277	The structures inventory summary form

3. Document Navigation

To find specific advice on a particular question within the risk assessment, please follow the corresponding hyperlink to all questions listed in the tables below.

[NOTE: in electronic format, to return the original page following selection of a hyperlink, press ALT and LEFT ARROW together.]

3.1. Culverts

	Risk Assessment Question	Hyperlink for Guidance
A.1.	A.1.1. What is the structural form?	Form Roads 277 Culverts (1 of 2) Section 6.1.1.
	A.1.2. What is the constituent material?	Form Roads 277 Culverts (1 of 2)
	A.1.3. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?	Section 6.1.2.
A.2.	A.2.1. What is the environment in, and around, the culvert?	Form Roads 277 Culverts (1 of 2)
	A.2.2. What was access for the GI?	Section 6.1.3.
A.3.	A.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Culverts Section 6.1.6.
	A.3.2. What is the scour risk rating?	Form Roads 277 Culverts (1 of 2) Section 6.1.7.
	A.3.3. Does the structure form part of the post flood inspection?	Section 6.1.8.
	A.3.4. Has the culvert been assessed for normal traffic, and if so, does its assessed capacity meet current standards?	Section 6.1.9.
	A.3.5. If the culvert has been assessed, what condition factor was used for assessment?	Section 6.1.10.
	A.3.6. What is the age of the culvert in relation to its approximate or known design life?	Form Roads 277 Culverts (1 of 2) Section 6.1.11.
A.4.	A.4.1. What is the approximate cover above the culvert?	Form Roads 277 Culverts (2 of 2) Section 6.1.12.
	A.4.2. What loading is typically applied to the structure?	Form Roads 277 Culverts (1 of 2) Section 6.1.13.
	A.4.3. What is the Annual Average Hourly HGV Flow?	Section 6.1.14.
	A.4.4. What is the Road Surface Category?	Inspection Pro Forma – Culverts Section 6.1.15.

3.2.Single Span Bridges

	Risk Assessment Question	Hyperlink for Guidance
B.1.	B.1.1. What is the structural form?	Form Roads 277 Single Span Bridges (1 of 2) Section 7.1.1.
	B.1.2. What is the constituent material?	Form Roads 277 Single Span Bridges (1 of 2) Section 7.1.2.
	B.1.3. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?	Section 6.1.2.
B.2.	B.2.1. What does the bridge span?	Form Roads 277 Single Span Bridges (1 of 2)
	B.2.2. What was access for the GI?	Form Roads 277 Single Span Bridges (1 of 2) Section 7.1.3.
	B.2.3. What is the maximum height beneath the bridge?	Form Roads 277 Single Span Bridges (1 of 2)
	B.2.4. What is the span of the bridge?	Form Roads 277 Single Span Bridges (2 of 2)
B.3.	B.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Single Span Bridges Section 6.1.6.
	B.3.2. Is the structure experiencing possible concrete attack?	Inspection Pro Forma – Single Span Bridges Section 7.1.4.
	B.3.3. Does this structure have a history of interventions to remove loose concrete?	Section 7.1.5.
	B.3.4. What is the scour risk rating?	Form Roads 277 Single Span Bridges (1 of 2) Section 6.1.7.
	B.3.5. Does the structure form part of the post flood inspection?	Section 6.1.8.
	B.3.6. Has the bridge been assessed for normal traffic, and if so, what is its assessed capacity to current standards?	Section 6.1.9.
	B.3.7. If the bridge has been assessed, what condition factor was employed for the bridge?	Section 6.1.10.
	B.3.8. What is the age of the structure in relation to its approximate or known design life?	Form Roads 277 Single Span Bridges (1 of 2) Section 6.1.11.
B.4.	B.4.1. What loading is typically applied to the structure?	Section 6.1.13.
	B.4.2. What is the Annual Average Hourly HGV Flow?	Section 6.1.14.
	B.4.3. What is the Road Surface Category?	Inspection Pro Forma – Single Span Bridges Section 6.1.15.

3.3. Multi Span Bridges

	Risk Assessment Question	Hyperlink for Guidance
C.1.	C.1.1. What is the structural form?	Form Roads 277 – Multi Span Bridges (1 of 2) Section 7.1.1.
	C.1.2. What is the constituent material?	Form Roads 277 – Multi Span Bridges (1 of 2) Section 7.1.2.
	C.1.3. What is the articulation of the bridge?	Form Roads 277 – Multi Span Bridges (1 of 2) Section 8.1.1.
	C.1.4. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?	Section 6.1.2.
C.2.	C.2.1. What does the bridge span?	Form Roads 277 – Multi Span Bridges (1 of 2)
	C.2.2. What was access for the GI?	Form Roads 277 – Multi Span Bridges (1 of 2) Section 8.1.2.
	C.2.3. What is the maximum height beneath the bridge?	Form Roads 277 – Multi Span Bridges (1 of 2)
	C.2.4. What level of access is there to the bridge spans?	Form Roads 277 – Multi Span Bridges (2 of 2)
C.3.	C.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Multi Span Bridges Section 6.1.6.
	C.3.2. Is the structure experiencing possible concrete attack?	Inspection Pro Forma – Multi Span Bridges Section 7.1.4.
	C.3.3. Does this structure have a history of interventions to remove loose concrete?	Section 7.1.5.
	C.3.4. What is the scour risk rating?	Section 6.1.7.
	C.3.5. Does the structure form part of the post flood inspection?	Section 6.1.8.
	C.3.6. Has the bridge been assessed for normal traffic, and if so, what is its assessed capacity to current standards?	Section 6.1.9.
	C.3.7. If the bridge has been assessed, what condition factor was employed for the bridge?	Section 6.1.10.
	C.3.8. What is the age of the structure in relation to its approximate or known design life?	Form Roads 277 – Multi Span Bridges (1 of 2) Section 6.1.11.
C.4.	C.4.1. What loading is typically applied to the structure?	Section 6.1.13.
	C.4.2. What is the Annual Average Hourly HGV Flow?	Section 6.1.14.
	C.4.3. What is the Road Surface Category?	Inspection Pro Forma – Multi Span Bridges Section 6.1.15.

3.4. Gantries and Footbridges

	Risk Assessment Question	Hyperlink for Guidance
D.1.	D.1.1. What is the structural form?	Section 7.1.1.
	D.1.2. What is the constituent material?	Form Roads 277 – Gantries and Footbridges (1of 2) Section 7.1.2.
	D.1.3. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?	Section 6.1.2.
D.2.	D.2.1. What does the structure span?	Form Roads 277 – Gantries and Footbridges (1of 2)
	D.2.2. What was access for the GI?	Form Roads 277 – Gantries and Footbridges (1of 2)
	D.2.3. What is the maximum height beneath the structure?	Form Roads 277 – Gantries and Footbridges (1of 2)
	D.2.4. What level of access is there to the structure spans?	Form Roads 277 – Gantries and Footbridges (2 of 2)
D.3.	D.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Gantries and Footbridges Section 6.1.6.
	D.3.2. Is the structure experiencing possible concrete attack?	Inspection Pro Forma – Gantries and Footbridges Section 7.1.4.
	D.3.3. Does this structure have a history of interventions to remove loose concrete?	Section 7.1.5.
	D.3.4. What is the scour risk rating?	Section 6.1.7.
	D.3.5. Does this structure form part of the post flood inspection?	Section 6.1.8.
	D.3.6. Has the structure been assessed, and if so, what is its assessed capacity to current standards?	Section 6.1.9.
	D.3.7. If the structure has been assessed, what condition factor was employed for the structure?	Section 6.1.10.
	D.3.8. What is the age of the structure in relation to its approximate or known design life?	Form Roads 277 – Gantries and Footbridges (1of 2) Section 6.1.11.
D.4.	D.4.1. What loading is typically applied to the structure?	Form Roads 277 – Gantries and Footbridges (1 of 2) Form Roads 277 – Gantries and Footbridges (2 of 2) Section 6.1.13.

3.5. Retaining Walls

	Risk Assessment Question	Hyperlink for Guidance
E.1.	E.1.1. What is the structural form?	Form Roads 277 – Retaining Walls (1 of 2) Section 10.1.1.
	E.1.2. What is the constituent material?	Form Roads 277 – Retaining Walls (1 of 2) Section 10.1.2.
	E.1.3. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?	Section 6.1.2.
E.2.	E.2.1. What is the retaining wall adjacent to?	Section 10.1.3.
	E.2.2. What was access for the GI?	Form Roads 277 – Retaining Walls (2 of 2) Section 10.1.4.
	E.2.3. What is the maximum retained height?	Form Roads 277 – Retaining Walls (2 of 2) Section 10.1.4.
E.3.	E.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Retaining Walls Section 6.1.6.
	E.3.2. Is the structure experiencing possible concrete attack?	Inspection Pro Forma – Retaining Walls Section 7.1.4.
	E.3.3. Does this structure have a history of interventions to remove loose concrete?	Section 7.1.5.
	E.3.4. What is the environment around the retaining wall?	Form Roads 277 – Retaining Walls (1 of 2)
	E.3.5. What is the scour risk rating?	Section 6.1.7.
	E.3.6. Does the structure form part of the post flood inspection?	Section 6.1.8.
	E.3.7. Has the retaining wall been assessed, and if so, what is its assessed capacity to current standards?	Section 10.1.5.
	E.3.8. If the retaining wall has been quantitatively assessed, what condition factor was used for the assessment?	Section 6.1.10.
	E.3.9. What is the age of the retaining wall in relation to its approximate or known design life?	Form Roads 277 – Retaining Walls (1 of 2) Section 6.1.11.
E.4.	E.4.1. What loading is typically applied to the structure?	Section 10.1.6.
	E.4.2. What is the Annual Average Hourly HGV Flow?	Section 6.1.14.
	E.4.3. What is the Road Surface Category?	Inspection Pro Forma – Retaining Walls Section 6.1.15.

3.6.Technology Structures

	Risk Assessment Question	Hyperlink for Guidance
F.1.	F.1.1. Is the structure a standard design (more than 10 in the inspection programme)?	Form Roads 277 – Technology Structures (1 of 2) Section 11.1.1.
	F.1.2. What is the foundation type?	Form Roads 277 – Technology Structures (1 of 2) Form Roads 277 – Technology Structures (2 of 2) Section 11.1.2.
	F.1.3. Is the structure classed as a complex structure, special structure, rail structure or exposed to a severe environment?	Section 6.1.2.
F.2.	F.2.1. What was access for the GI?	Form Roads 277 – Technology Structures (2 of 2) Section 11.1.3.
F.3.	F.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?	Inspection Pro Forma – Technology Structures Section 6.1.6.
	F.3.2. What is the age of the structure in relation to its approximate or known design life?	Form Roads 277 – Technology Structures (1 of 2) Section 6.1.11.
F.4.	F.4.1. Does the structure have fixed Advance Direction Signs (ADS) and/or Electronic Signs?	Form Roads 277 – Technology Structures (1 of 2) Section 11.1.4.

4. Background Information

4.1. General Inspections

Structures within the scope of CS 450 require General Inspections every 24-months and not exceeding three years. These inspections assess the physical condition of all visible elements on a highways structure, without the need for special access equipment or traffic management. The frequency of General Inspections cannot be increased through risk assessment.

General Inspections are quicker and easier to deliver than Principal Inspections, posing less risk as they do not require close-up inspection of the entire structure.

An Inspection Pro-Forma is completed for each General Inspection undertaken, detailing the overall condition of the structure, as well as more detailed defect assessments for individual elements (e.g. foundations, bearings, main beams, expansion joints, and parapets). The extent and severity of each defect is recorded, and the type of remedial work required specified (e.g. replace, paint, and monitor). Each defect is ranked in order of priority as described in the Welsh Government Structures Inspection Manual. Alongside each defect, an estimate of the cost of undertaking the remedial works is also recorded.

4.2. Principal Inspections

A Principal Inspection assesses the physical condition of all inspectable parts of a highway structure, providing more detailed information than a General Inspection. It determines the condition of all parts of the structure, the extent of any significant change or deterioration since the last Principal Inspection and any information relevant to the stability of the structure. It establishes the scope and urgency of any remedial works or other actions required before the next inspection. It may also highlight if there is a need to undertake any Special Inspections on specific areas of the structure. Additionally, it audits the accuracy of the main inventory data held for the structure.

CS 450 requires Principal Inspections to be carried out at six-year nominal intervals but allows substantial flexibility to extend this interval through Risk Assessment up to a maximum of twelve years.

4.3. Inspection Intervals

CS 450 permits the Principal Inspection interval to be increased from the 6-yearly frequency subject to a risk assessment and agreement with the TAA. Intervals may not exceed 12 years and can be 6, 8, 10 or 12 years, depending on the outcome of the risk assessment.

Decisions to vary inspection intervals should be based on data from biennial General Inspections. The Inspection Pro-Forma is crucial for risk assessments, with core data coming from it and Form Roads 277. Additional information strengthens the assessment, but misinformation can lead to false results. Risk assessments should inform, not replace, experienced engineering judgment, contributing to a holistic view of the structure.

4.4. Risk Assessing Inspection Intervals

The objective is to use biennial General Inspection data to assess the risk of unacceptable condition changes, informing the frequency of Principal Inspections. Engineers typically have a view on the risk level of a structure, influencing whether a six-year interval is necessary. Formal risk assessments confirm, challenge, or guide this judgment. Therefore, the PIIRA is reviewed after each General Inspection.

While an engineer on-site may consider limited criteria like current condition and age, a formal risk assessment offers a more comprehensive outlook. General Inspections assess the current condition, not future failure probability. Risk assessments should combine basic structural data, including condition, to evaluate the likelihood of deterioration and its potential consequences.

Appendix A describes the process for the development of the PIIRA scoring system and Appendix B examines the criteria for scoring the risks in terms of likelihood and consequence and explains how the scores are weighted to produce the final risk score for the structure.

4.5. Structures not Included for Risk Assessment

Structural types not included for risk assessment are Tunnels and Rock Protection Walls. In the case of tunnels, they number few in comparison with other structural types, and with each constituting a major regional structure, they are considered to be too high risk for consideration by the risk assessment process described here.

Some Rock Protection Walls are classed as structures and some are not; however, a 6-year Principal Inspection interval is recommended due to the structure's location being in an area of extreme environmental conditions where deterioration needs close monitoring. The PIIRA is therefore not applicable to these structures.

4.6. Risk Assessment

A risk assessment has been developed based on a mainly multiple-choice questionnaire format. There are six different risk assessments covering the major structural types, including:

- Culverts
- Single-span Bridges
- Multi-span bridges
- Gantries/Footbridges
- Retaining Walls
- Technology Structures

Of the six structural types included, each has an individual risk assessment/questionnaire, divided into four main categories of questions, which cover the structural factors and attributes which heavily influence the likelihood of deterioration and the consequences of failure. These categories are historical questions, inspection data questions, condition questions and usage questions.

4.6.1. Historical Questions

The historical set of questions obtains information about the structure's materials and form and compares them against what is known, historically, about the performance of such properties. For example, engineers know that brick arch structures experience different maintenance/deterioration issues to those of steel structures.

4.6.2. Inspection Questions

The inspection data set of questions evaluates how reliable existing knowledge of the structure's current condition is, based on the assumed effectiveness of obtaining information during the last inspection. For example, visually inspecting a motorway viaduct high over a river will prove more difficult than inspecting an access underbridge. The data obtained from the inspection of the former may, therefore, be less reliable than the latter. The level of access achieved for inspection should be considered as part of the risk assessment, as the true condition recorded on the Inspection Pro-Forma, may be compromised.

4.6.3. Condition Questions

The condition set of questions takes information about the bridges condition, mainly from the Inspection Pro-Forma. Other documents also hold important information about a structure's condition. A Structural Assessment Report should be available for most structures and will strengthen any risk assessment. If the structure has certain issues which have demanded further investigation, then any associated reports (e.g. Special Inspection Reports, CS 470 documents etc) should also be looked at.

4.6.4. Usage Questions

The usage set of questions focuses on capturing aspects which affect the significance of the loss of capacity and detectability. If there is a high live load element, such as wind, the capacity can drop below the required service strength with no visible signs of distress. In comparison, if the applied loading is primarily dead load, as the capacity reduces, due to deterioration for example, then distress is likely to be visible.

Each of these sets of questions have different levels of importance, and are weighted in order of importance, accordingly. The greater the influence the 'set' has on the risk assessment, the greater the weighting it is given. The weightings of all four 'sets' add up to 100 (i.e. the percentage total).

For example, a single-span bridge being risk assessed will be weighed as follows:

- Historical score – W = 20%
- Inspection score – W = 30%
- Condition score – W = 30%
- Usage score – W = 20%

In this case, points accumulated under Inspection and Condition questions are given greater influence in the overall risk assessment than those accumulated for Historical and Usage categories. For every question asked in the risk assessment, there are a range of scores available. For attributes expected to return a low likelihood of deterioration or minimal consequence, positive (+) points are awarded. Any attributes expected to return a high likelihood of deterioration or significant consequence, negative (-) points are awarded. If an attribute is expected to have little net return on the likelihood of deterioration or on the consequence, zero points are awarded.

On completing the risk assessment, a number of points will have been accumulated. The overall risk is inversely proportional to the number of points scored (i.e. the more points accumulated the lower the risk associated to the structure). Conversely, the fewer points accumulated the higher the risk associated to the structure.

A summary of the accumulated score and corresponding recommended Principal Inspection interval is shown in Table 1 below:

Accumulated Score	Recommended Principal Inspection Time Interval
$x < 20\%$	Maintain at 6 years
$20\% \le x < 40\%$	Consider increasing to 8 years
$40\% \le x < 60\%$	Consider increasing to 10 years
$x \ge 60\%$	Consider increasing to 12 years (maximum)

Table 1 - Scoring guidelines for risk assessment

Further background to the development of the scoring system can be found in Appendix A.
When completing the risk assessment, the scoring guidelines given in Table 1 should be used to guide and inform the engineer's judgement but not replace it.

4.7. Using the Risk Assessment Excel Spreadsheet

There are a number of questions throughout the questionnaire for each structure type that will necessitate a 6-year PI interval. At this point answering subsequent questions will not change the final PI inspection interval, however it is still worthwhile completing the risk assessment to provide a useful source of information and, should the mandatory 6-year PI interval be removed at some point in the future, then it will enable an easy update of the PIIRA.

All cells requiring input will either contain "Please Select Option" in red text and once answered the text will become black. The questions requesting input of the lowest BCI score and scour risk rating have their answer cells filled red until values are input, at which point they become light blue.

At the bottom of the questionnaire the cell containing the total score for the structure is filled red until either all the questions are answered, or a mandatory 6-year PI interval is generated, at which point it will change to light blue. This means if any questions have been missed it will be indicated by red fill of this cell. Similarly, the lowest BCI score and scour risk rating cells at the bottom of the form will also be filled red if they have not been completed earlier in the questionnaire.

5. Information Gathering for Desk Study

The first part of completing the risk assessment is to locate the relevant background information relating to the structure. The required documents are:

- The Form Roads 277;
- The most recent Inspection Pro Forma;

Other useful (*optional*) documents are:

- The most recent Principal Inspection Report;
- The most recent Structural Assessment Report;
- Any associated information (e.g. a Concrete Testing Report, CS 470 documentation).

The bulk of the risk assessment can be completed using the Form Roads 277 and Inspection Pro-Forma. Having additional information, however, will help the risk assessment process. The information from the Form Roads 277 can be verified against the information in the Integrated Roads Information System IRIS.

5.1. Form Roads 277

This form provides basic facts about the structure, including structural form, year of construction, design loading and surrounding environment.

5.2. Inspection Pro Forma

This document details the findings of the biennial General Inspection, providing recent condition data on the structure being risk assessed.

5.3. Principal Inspection Report

This provides a much more detailed insight into the structure's condition than that provided in the Inspection Pro Forma as it documents a physical, touching distance, inspection of all elements of the structure. If available, this should be used to reinforce the condition information seen on the Inspection Pro Forma.

5.4. Structural Assessment Report

A Structural Assessment Report will contain the assessed load capacity of the structure, as well as the condition factor. Bridge assessment programmes have been undertaken for a variety of reasons, particularly in the 1990's. These were initially carried out in preparation for heavier goods vehicles introduced in 1999 to comply with European legislation. Assessments have also been done to reflect changes in concrete, steel and design standards. These assessments, however, do not cover all structures on the road network. For structures that were assessed, detailed reports were produced, specifying their load capacities. These Structural Assessment Reports, if available, can be used to inform the risk assessment process.

5.5. Concrete Deterioration Special Investigation

Alternative additional investigations may have been undertaken to identify the presence of serious concrete deterioration. The visible indications should have been recognised at either General or Principal Inspection stage, but findings at those stages would not have been in-depth enough to enable an accurate analysis of the deterioration.

The causes of concrete deterioration can be attributed to either design and construction errors and / or environmental effects. A systematic analysis should be undertaken to determine the causes and extent of the damage before engineers can confidently restore the defective concrete. The source of the problems can range from an excessively slender design to poor workmanship; to shrinkage or insufficient contraction / expansion tolerances.

A risk assessment needs to consider whether environmental effects are known to be a major contributor to concrete deterioration. These environmental problems can take the form of alkali-silica reaction (ASR), alkali-carbonate reaction (ACR) and thaumasite sulphate attack (TSA). All three can be highly damaging to concrete and if present, will require investigation. When assessing the risks associated to any concrete structure, a history of concrete attack should be carefully considered. Knowledge of the geology of an area and typical aggregates used in concrete will be of benefit.

The Concrete Deterioration Special Investigation Report will assist in answering questions referring to the status of the structure with respect to any history of ASR, ACR or TSA.

5.6. Risk Assessment

After gathering all available information about a culvert, the risk assessment can then be completed. In all cases, the Bridge Inspection Pro Forma and Form Roads 277s will provide the majority of the information required.

6. A – Culverts

A culvert is a structure designed to channel water or provide passage under a road, typically used for drainage but can also be provided to enable mammals to cross. It shall have a span exceeding 900mm to be classified as a highway structure and shall have fill material between its uppermost point and the road running courses. Culverts are usually rectangular or circular in profile (e.g., boxes or pipes) but can also be formed of arches, cantilevered walls with a separate deck, or portal frames with a non-structural invert.

6.1. Culverts Questionnaire

All questions capable of being answered by directly taking information from an Inspection Pro Forma or Form Roads 277 are illustrated in Figure 1 to 3. Other questions, which may not have direct answers in either of these forms, are described below. The advice given on these questions is applicable for all other structural types as noted beneath each question.

6.1.1. Question A.1.1. What is the structural form?

The rationale behind the structural forms chosen is illustrated in Table 2 below:

Structural Form	**Rationale**
Box/Pipe	Box culverts could be precast concrete or cast in situ and pipe culverts may comprise corrugated steel or precast pipes with reinforced concrete headwalls.
Arch	Arch culverts typically comprise masonry.
Cantilevered walls with a separate deck	This type would commonly be reinforced concrete.
Portal frame with non-structural invert	This type would commonly be reinforced concrete.

Table 2 - Culvert Structural Form

6.1.2. Question A.1.3. Is the structure classed as a complex structure, special structure, rail structure, exposed to a severe environment or at a medium or high risk of damage due to flooding?

The advice given here also applies to **B.1.3., C.1.4., D.1.3., E.1.3.** and **F.1.3.**

Complex structures, special structures, rail structures, structures exposed to a severe environment and structures at a medium or high risk of damage due to flooding cannot increase their PI interval through risk assessment and require a mandatory 6-year PI interval.

Complex structures and special structures are defined within CS 450.

CS 450 defines retaining walls with a retained height greater than 7.0m as complex structures but allows them to have a risk-based PI frequency.

Rail structures are classed as structures which could affect an operational railway if a failure took place.

6.1.3. Question A.2.2. What was access for the GI?

The level of access for a GI gives an indication on the reliability of the inspection information gathered. If access is limited, the GI may not pick up and record defects which exist but are not easily visible, thus reducing the reliability of the GI. The rationale behind the choices for levels of GI access is shown in Table 3 below:

Answer	**Rationale**
Confined	Confined should be selected if the culvert is classed as a confined space or if access to it is not possible. Confined spaces cannot be accessed during a GI therefore very little if any of the soffit will be visible.
Partial	Partial access should be selected if some, but not all of the critical elements are visible.
Full	Full access should be selected if there is good visibility to all parts of the structure.

Table 3 - Access for GI

6.1.4. Using the Form Roads 277 – Culverts

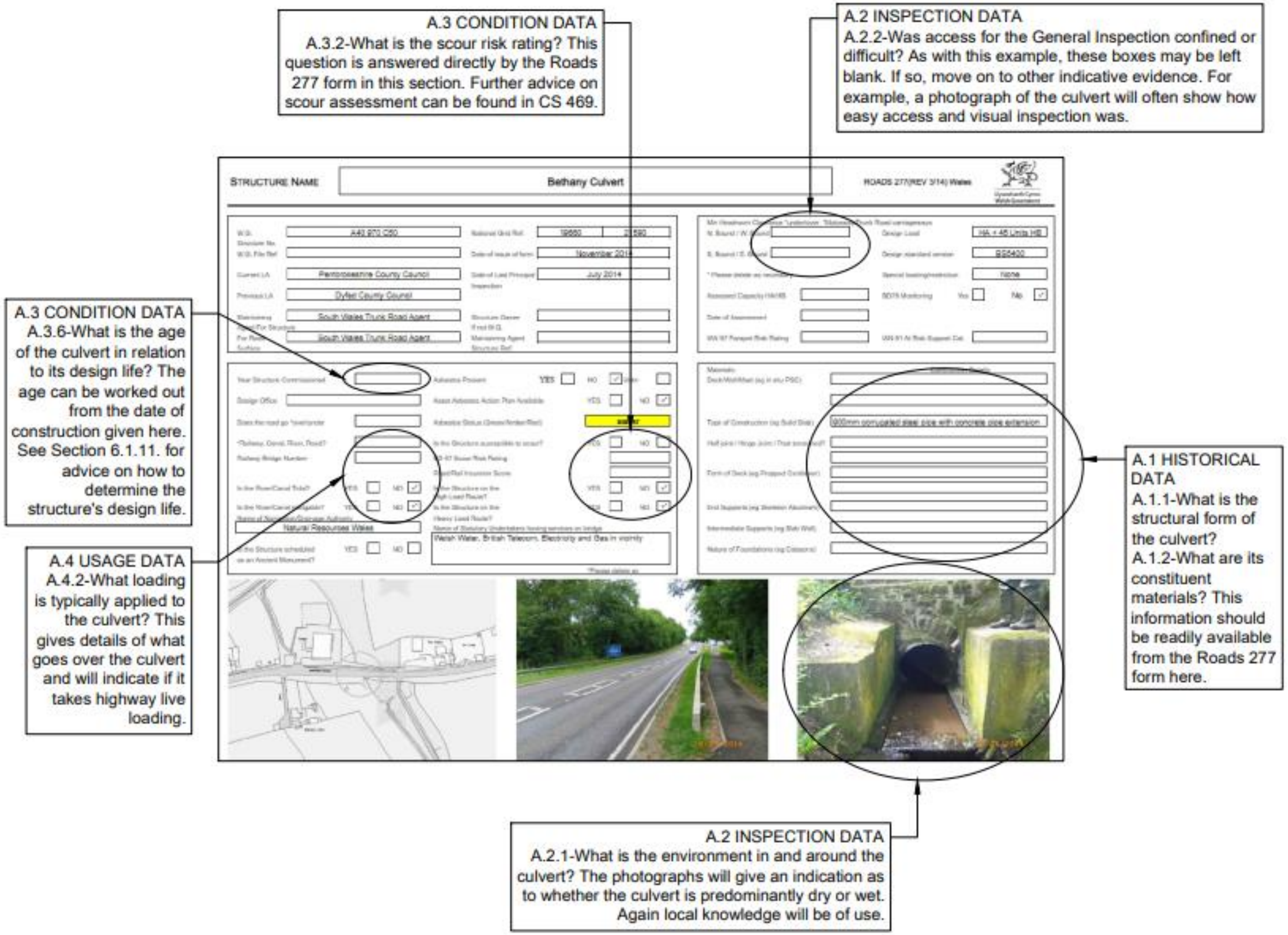
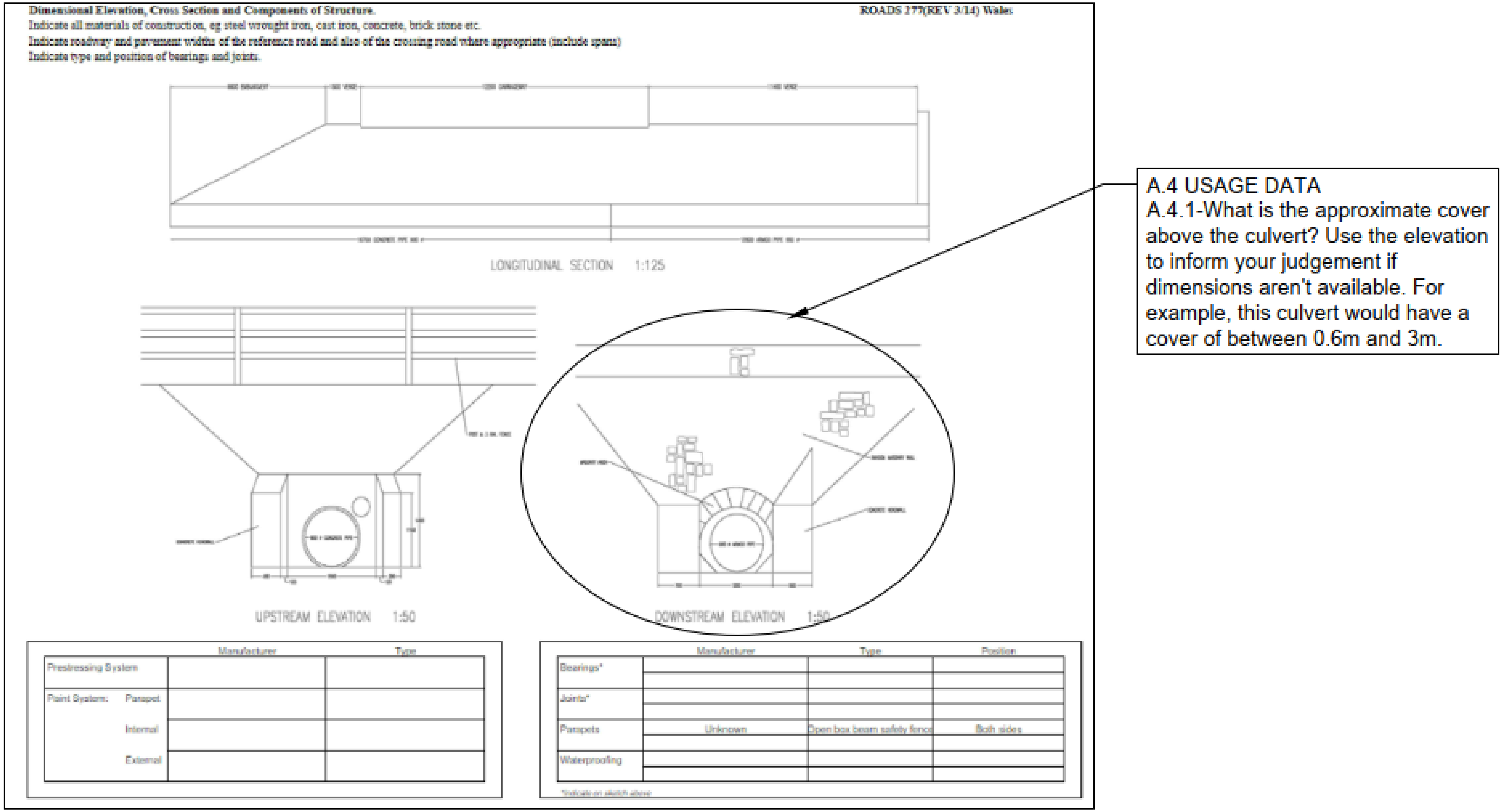


Figure 1 Using the Form Roads 277 to risk assess culverts (1 of 2)



Dimensional Elevation, Cross Section and Components of Structure.
Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)
Indicate type and position of bearings and joints.

ROADS 277(REV 3/14) Wales

LONGITUDINAL SECTION 1:125

UPSTREAM ELEVATION 1:50

DOWNSTREAM ELEVATION 1:50

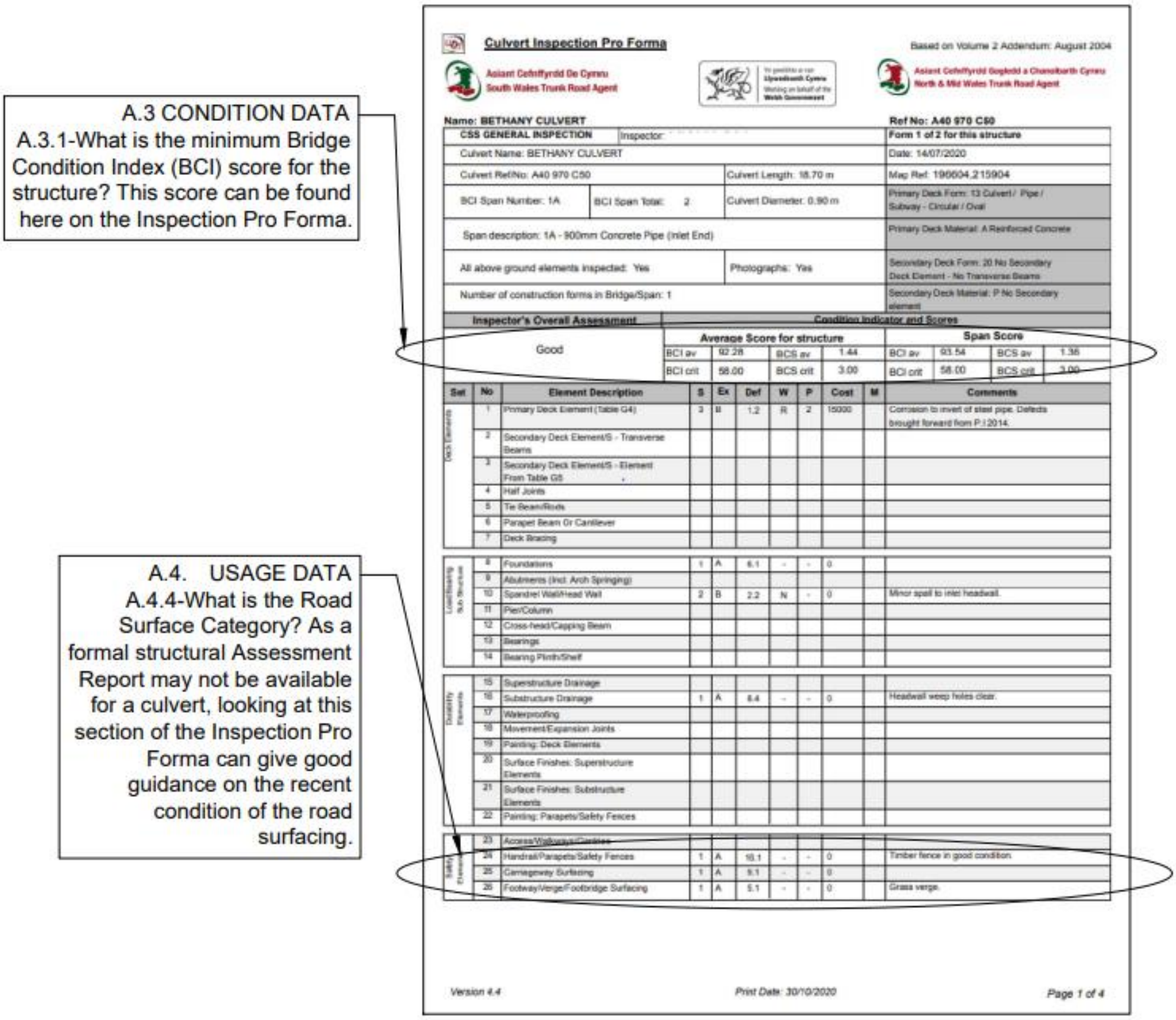
		Manufacturer	Type
Prestressing System			
Paint System:	Parapet		
	Internal		
	External		

	Manufacturer	Type	Position
Bearings*			
Joints*			
Parapets	Unknown	Open box beam safety fence	Both sides
Waterproofing			

*Indicate on sketch above

Figure 2 Using the Form Roads 277 to risk assess culverts (2 of 2)

6.1.5. Using the Inspection Pro Forma – Culverts



Culvert Inspection Pro Forma

Based on Volume 2 Addendum: August 2004

Asiant Cefnffyrdd De Cymru
South Wales Trunk Road Agent

Asiant Cefnffyrdd Gogledd a Chanolbarth Cymru
North & Mid Wales Trunk Road Agent

Name: BETHANY CULVERT — Ref No: A40 970 C50

CSS GENERAL INSPECTION	Inspector:		Form 1 of 2 for this structure
Culvert Name: BETHANY CULVERT			Date: 14/07/2020
Culvert Ref/No: A40 970 C50		Culvert Length: 18.70 m	Map Ref: 196604,215904
BCI Span Number: 1A	BCI Span Total: 2	Culvert Diameter: 0.90 m	Primary Deck Form: 13 Culvert / Pipe / Subway - Circular / Oval
Span description: 1A - 900mm Concrete Pipe (Inlet End)			Primary Deck Material: A Reinforced Concrete
All above ground elements inspected: Yes		Photographs: Yes	Secondary Deck Form: 20 No Secondary Deck Element - No Transverse Beams
Number of construction forms in Bridge/Span: 1			Secondary Deck Material: P No Secondary element

Inspector's Overall Assessment	Condition Indicator and Scores							
	Average Score for structure				Span Score			
Good	BCI av	92.28	BCS av	1.44	BCI av	93.54	BCS av	1.36
	BCI crit	58.00	BCS crit	3.00	BCI crit	58.00	BCS crit	3.00

Set	No	Element Description	S	Ex	Def	W	P	Cost	M	Comments
Deck Elements	1	Primary Deck Element (Table G4)	3	B	1.2	R	2	15000		Corrosion to invert of steel pipe. Defects brought forward from P.I 2014.
	2	Secondary Deck Element/S - Transverse Beams								
	3	Secondary Deck Element/S - Element From Table G5								
	4	Half Joints								
	5	Tie Beam/Rods								
	6	Parapet Beam Or Cantilever								
	7	Deck Bracing								
Load Bearing Sub Structure	8	Foundations	1	A	6.1	-	-	0		
	9	Abutments (Incl. Arch Springing)								
	10	Spandrel Wall/Head Wall	2	B	2.2	N	-	0		Minor spall to inlet headwall.
	11	Pier/Column								
	12	Cross-head/Capping Beam								
	13	Bearings								
	14	Bearing Plinth/Shelf								
Durability Elements	15	Superstructure Drainage								
	16	Substructure Drainage	1	A	6.4	-	-	0		Headwall weep holes clear.
	17	Waterproofing								
	18	Movement/Expansion Joints								
	19	Painting: Deck Elements								
	20	Surface Finishes: Superstructure Elements								
	21	Surface Finishes: Substructure Elements								
	22	Painting: Parapets/Safety Fences								
Safety Elements	23	Access/Walkways/Gantries								
	24	Handrail/Parapets/Safety Fences	1	A	10.1	-	-	0		Timber fence in good condition.
	25	Carriageway Surfacing	1	A	5.1	-	-	0		
	26	Footway/Verge/Footbridge Surfacing	1	A	5.1	-	-	0		Grass verge.

Version 4.4 — Print Date: 30/10/2020 — Page 1 of 4

Figure 3 Using the Inspection Pro Forma to risk assess culverts

6.1.6. Question A.3.1. What is the lowest Bridge Condition Index (BCI) score for the structure?

The advice given here also applies to **B.3.1., C.3.1., D.3.1., E.3.1.** and **F.3.1.**

The BCI_{crit} score is a measure of the condition of the structure based solely on the critical elements and this value is found on the latest Inspection Pro Forma. The $BCI_{average}$ score averages the BCI scores across the structure. It has been noted that in a very small number of structures the $BCI_{average}$ score is less than the BCI_{crit} score. The lowest BCI score should be input to the risk assessment.

A BCI score equal to 40 and greater will be shown in black text and a score between 0 and 39.99 will be shown in red text and will trigger a mandatory 6-year PI interval. In both cases the score will automatically be entered at the foot of the questionnaire.

6.1.7. Question A.3.2 What is the scour risk rating?

The advice given here also apples to **B.3.4., C.3.4., D.3.4.** and **E.3.5.**

BD 97 The Assessment of Scour and other Hydraulic Actions at Highway Structures has been recently superseded by CS 469 Management of scour and other hydraulic actions at highway structures. Due to changes to the scour risk rating scoring system and the fact that it will take time to translate the risk ratings of all the affected structures from BD 97 to CS 469, the PIIRA can receive scour risk scores from either standard. The risk rating will be shown at the foot of the questionnaire. A summary of the ratings from both standards is shown in the Table 4 below:

BD 97	**CS 469**	**Rationale**
Scour risk rating 1-4 inclusive	Type 1 High Type 1 Medium Type 2 High	Mandatory 6-year PI interval
Scour risk rating 5	Type 1 Low Type 2 Medium Type 2 Low	PI frequency is determined by the PIIRA

Table 4 - Scour Risk Rating

6.1.8. Question A.3.3. Does the structure form part of the post flood inspection?

The advice given here also applies to **B.3.5., C.3.5., D.3.5.** and **E.3.6.**

A list of all structures susceptible to scour will be maintained in accordance with CS 469 and a risk-based approach shall be taken to decide when emergency inspections are carried out in accordance with the Welsh National Application Annex (WNAA).

6.1.9. Question A.3.4. Has the structure been assessed for normal traffic and if so, what is its assessed capacity to current standards?

The advice given here also applies to **B.3.6., C.3.6.** and **D.3.6.**

Normal traffic is defined as ALL Model 1 or ALL Model 2 in accordance with CS 454 and 40 tonnes HA in accordance with BD 21. The presence of a Structural Assessment Report will affect the risk assessment inputs as illustrated in Table 5 below:

Answer	Rationale
Yes – 40T LL capacity	This option reflects a level of certainty regarding the status, with respect to assessment where an assessment has been done.
Assessment not required	If the structure is new an assessment will not be required or in the case of a retaining wall, it may be sufficiently small to not warrant an assessment.
CS 470 monitoring programme	Post assessment the structure has been found to be sub-standard and is now being actively managed.
No-a load limit is in place	Post assessment the structure has been found to be under strength and a load limit is in place.
No assessment	No assessment has been done.
Don’t know	It is not known if an assessment has been done.

Table 5 - Assessment Options

6.1.10. Question A.3.5. If the culvert has been assessed, what condition factor was used for assessment?

The advice given here also applies to **B.3.7., C.3.7., D.3.7.** and **E3.8.**

The condition factor used in assessment will affect the risk assessment inputs as illustrated in Table 6 below:

Condition Factor	Rationale
Greater than 0.90	If a quantitative “assessment by calculation” was done, the Condition Factor will be stated in the Assessment Report.
Between 0.70 and 0.90	
Between 0.30 and 0.70	
None used	If a qualitative “assessment” was done, no Condition Factor will have been used, so “none used” will be applicable.
Not applicable	If no assessment has been done.

Table 6 - Condition Factor used in Assessment

6.1.11. Question A.3.6. What is the age of the structure in relation to its approximate or known design life?

The advice given here also applies to **B.3.8., C.3.8., D.3.8., E.3.9.** and **F.3.2.**

The Design Life for a structure can vary from 30 years up to 120 years, depending on the type of structure. On occasions, a bridge owner may also have stipulated a different design life from what would normally be expected. Consequently, it is important to validate the value for each structure. A structure which is less than 70% of its Design Life, but not new, is expected to be at lowest risk of deteriorating. Whereas a new bridge is yet to be ‘proven’, and an old bridge is approaching the end of its Design Life and may be expected to deteriorate.

For example, if a structure is 42 years old and has a normal design life of 120 years, it is at 35% of its design life and therefore the age of the structure relative to its design life is “5%<design life<70%”.

If the design life of the structure is not known or it was constructed before 1975 then there is an option to enter this and the risk assessment will take it into account.

6.1.12. Question A.4.1. What is the approximate cover above the culvert?

The approximate cover above the culvert can be determined from the elevation drawing on page 2 of the Form Roads 277. If no dimensions are available, use the drawing and photographs to inform a judgement on the approximate cover. Where the cover varies from one end of the culvert to the other, then the smaller dimension should be used in the risk assessment.

6.1.13. Question A.4.2. What loading is typically applied to the structure?

The advice given here also applies to **B.4.1., C.4.1., D.4.1.** and **E.4.1.**

Details of the design load for the structure can be found on the Form Roads 277 which, together with local knowledge, can inform the loading typically applied to the structure. When considering footbridges, looking at the location of the bridge and its proximity to amenities and services can inform whether the structure lies on a busy route and will therefore be subject to heavy usage. If the footbridge has solid elements on elevation which would attract a large wind load, then it will be affected by the wind. The height of the parapets will indicate if the footbridge was designed for cyclists or equestrian use.

6.1.14. Question A.4.3. What is the Annual Average Hourly HGV flow?

The advice given here also applies to **B.4.2., C.4.2.** and **E.4.2.**

The Annual Average Hourly HGV flow is available on the Department for Transport website, and this will give the most accurate traffic count data.

Traffic both above and below a retaining wall is applicable.

6.1.15. Question A.4.4. What is the road surface category?

The advice given here also applies to **B.4.3., C.4.3.** and **E.4.3.**

Road surface category will be quoted in an assessment report, however if no assessment report is available, the condition of the road surface will be detailed on the Inspection Pro Forma. This will give good guidance on the recent condition status of the road surfacing and can inform the road surface category.

7. B - Single-Span Bridges

A single span bridge spans a road, watercourse or railway line without the need for intermediate pier supports.

7.1. Single-Span Bridges Questionnaire

All questions capable of being answered by directly taking information from an Inspection Pro Forma or Form Roads 277 are illustrated in Figures 4 to 6 below. More detail and other questions, which may not have direct answers in either of these forms, are described below. The advice given on these subjects may be used for all other structural types, not just for bridges. Any questions not illustrated on the Inspection Pro Forma or Form Roads 277 or described below can be answered by referring to the Culverts section.

7.1.1. Question B.1.1. What is the structural form?

The advice given here also applies to **C.1.1.** and **D.1.1.**

The structural form of a bridge can affect the likelihood of deterioration since historical performance (e.g., any known problems with durability or robustness) and the degree of redundancy varies between specific forms of construction. The rationale behind many of the structural forms chosen is illustrated in the Table 7 below:

Structural Form	**Rationale**
Beam and slab/Jack Arch/Filler Beam/Truss	With a deck comprising a number of individual members, in the unlikely event of failure, collapse can be instigated from a weakness in one part of one member.
Slab	Unlike the beam and slab deck, the collapse of a slab deck needs multiple progressive failures to occur. Cracks should be picked up during biennial GI giving plenty of scope for a management programme of the bridge to be started.
Arch	An arch, like a slab, will fail progressively with defects like cracks becoming apparent over time. These would get picked up at biennial GI allowing a management programme to be implemented.
Integral with bank seat abutments/box structure	An integral bridge, with the added benefit of being on bank seats, has the positive characteristics of not having bearings or joints, as well as having been designed to take integral loads. In summary, a good durable form.
Integral with full height abutments	Like all integral bridges, this option represents a durable structure undergoing progressive failure. The presence of full-height abutments, however, means the soil interactions are complex and less predictable. In addition, the relatively recent adoption of this form means that we lack an historical perspective on potential issues related to them.

Table 7 - Bridge Structural Form

7.1.2. Question B.1.2. What is the constituent material?

The advice given here also applies to **C.1.2.** and **D.1.2.**

Similar to structural form, the main factor to consider when reviewing how constituent materials of a bridge could affect the likelihood of deterioration is historical performance. The rationale behind each of the constituent materials chosen is illustrated in Table 8 below:

Constituent Material	**Rationale**
Modern steel post 1975, welded	Modern steel has much less variability in quality and strength. Improved welds mean that few problems should be encountered with this product.
Steel pre 1975, wrought iron, riveted	Pre-1975 steel has a more variable quality on account of its age. Although multiple rivet arrangements give redundancy if one or more fails, there are, however, often corrosion traps.
Cast iron	Historical knowledge tells us that brittle failure can stem from crack propagation in cast-iron structures. A 6 monthly special PI is required in accordance with CS 450.
Plate bonded reinforced concrete	A recent development, CS 450 requires a 6 monthly inspection for the first two years to check bonding and the general condition. The presence of plate-bonding often indicates that the original structure has been strengthened.
In-situ reinforced concrete	Reinforced concrete is a widely used material with a good track record over 100+ years. We know how it behaves. Fatigue problems are very rare.
Precast prestressed concrete	A factory-made product, quality and durability should be of high standard.
Post tensioned concrete	Some forms of post-tensioned bridges (CS 465) are susceptible to catastrophic brittle failure. A Post-Tensioned Special Investigation may have been done or be required. Further investigation of the risk is required here.
Brick/Stone	Brick / stone forms of construction tend to be low stress in nature. Decay is visible and gradual and would be spotted by biennial GI.

Table 8 - Constituent material

7.1.3. Question B.2.2. What was access for the GI?

The level of access for a GI gives an indication on the reliability of the inspection information gathered. If access is limited, the GI may not pick up and record defects which exist but are not easily visible, thus reducing the reliability of the GI. The rationale for the choices of GI access is shown in Table 9 below:

Access	Rationale
Confined and difficult	Confined and difficult should be selected If access is difficult resulting in very little of the structure being visible at GI.
Key areas not visible	Key areas not visible should be selected if critical elements are not visible during the GI.
Access to over half of deck and abutments	Access to over half of deck and abutments should be selected if access allows good visibility of over half of the structure.
Full access	Full access should be selected if there is good visibility to all parts of the structure.

Table 9 - Single Span Bridge GI Access

7.1.4. Question B.3.2. Is the structure undergoing possible concrete attack?

The advice given here also applies to **C.3.2., D.3.2.** and **E.3.2.**

This risk assessment asks the user to consider whether the structure is undergoing possible concrete attack and the Bridge Inspection Pro Forma should record any damage observed which is suspected of being caused by concrete attack. These problems can often take the form of *alkali-silica reaction* (ASR), *alkali-carbonate reaction* (ACR) and *thaumasite sulphate attack* (TSA). All three are very damaging to concrete and if present will need investigation.

- **Alkali-Silica Reaction (ASR)** - Certain types of aggregate with poor alkali resistance interact with alkaline fluids in the pores of the concrete to form a silica gel around the surface. This gel absorbs moisture, causing it to expand, and ultimately leads to cracking and further deterioration of the concrete.
- **Alkali-Carbonate Reaction (ACR)** – As with ASR, the alkaline environment of concrete attacks the aggregate that includes reactive particles. In ACR, the alkaline reacts with dolomite limestone, replacing it with less stable and expansive products. This reaction usually occurs early, and structures may show cracking within five years after construction. Over time, the ACR products create a ‘rim’ around the aggregate, weakening the bond and creating micro-cracks and voids. Cracks allow ingress of water, sulphates, and chlorides to the interior of the concrete, leading to durability issues such as freeze/thaw damage, sulphate attack or steel corrosion.
- **Thaumasite Sulphate Attack (TSA)** - The thaumasite form of sulphate attack requires a source of sulphate and carbonate. Thaumasite can occur naturally as an alteration mineral and can also form in concrete and mortar. The cement hydration products normally present, mainly calcium silicate hydrate and calcium hydroxide, are decomposed as a result of both sulphate attack and of carbonation. Since it is the calcium silicate hydrate in concrete that provides most of the strength, thaumasite formation results in severe weakening.

An illustration of how the risk assessment approaches the presence of concrete deterioration / attack is shown in Table 10 below:

Type of Concrete Deterioration/Attack	Rationale
TSA, SAR, ACR and other risks as yet not investigated or assessed	The threat of serious concrete deterioration not yet been assessed or is in the process of being investigated. Clearly this unknown constitutes a major risk and is given a lower score accordingly.
TSA, SAR, ACR and other risks investigated or assessed	The threat of serious concrete deterioration was noted some time back and was investigated and assessed accordingly. This clearly constitutes a positive development. Where appropriate a Management Plan will have been produced and implemented.
No signs of concrete attack / not applicable	Note that a structure NOT suffering concrete attack does not constitute a positive. In risk assessment it should be the norm not a bonus and is marked as such.
Don't know	It is not known if the structure is undergoing concrete attack.

Table 10 - Concrete deterioration/attack

7.1.5. Question B.3.3. Does this structure have a history of interventions to remove loose concrete?

The advice given here also applies to **C.3.3., D.3.3.** and **E.3.3.**

If the structure has a history of interventions to remove loose concrete, this will be recorded within the maintenance information. IRIS SMS has the facility to record instances of concrete removed and serves as a record of concrete removal.

7.1.6. Using the Form Roads 277 – Single-Span Bridges

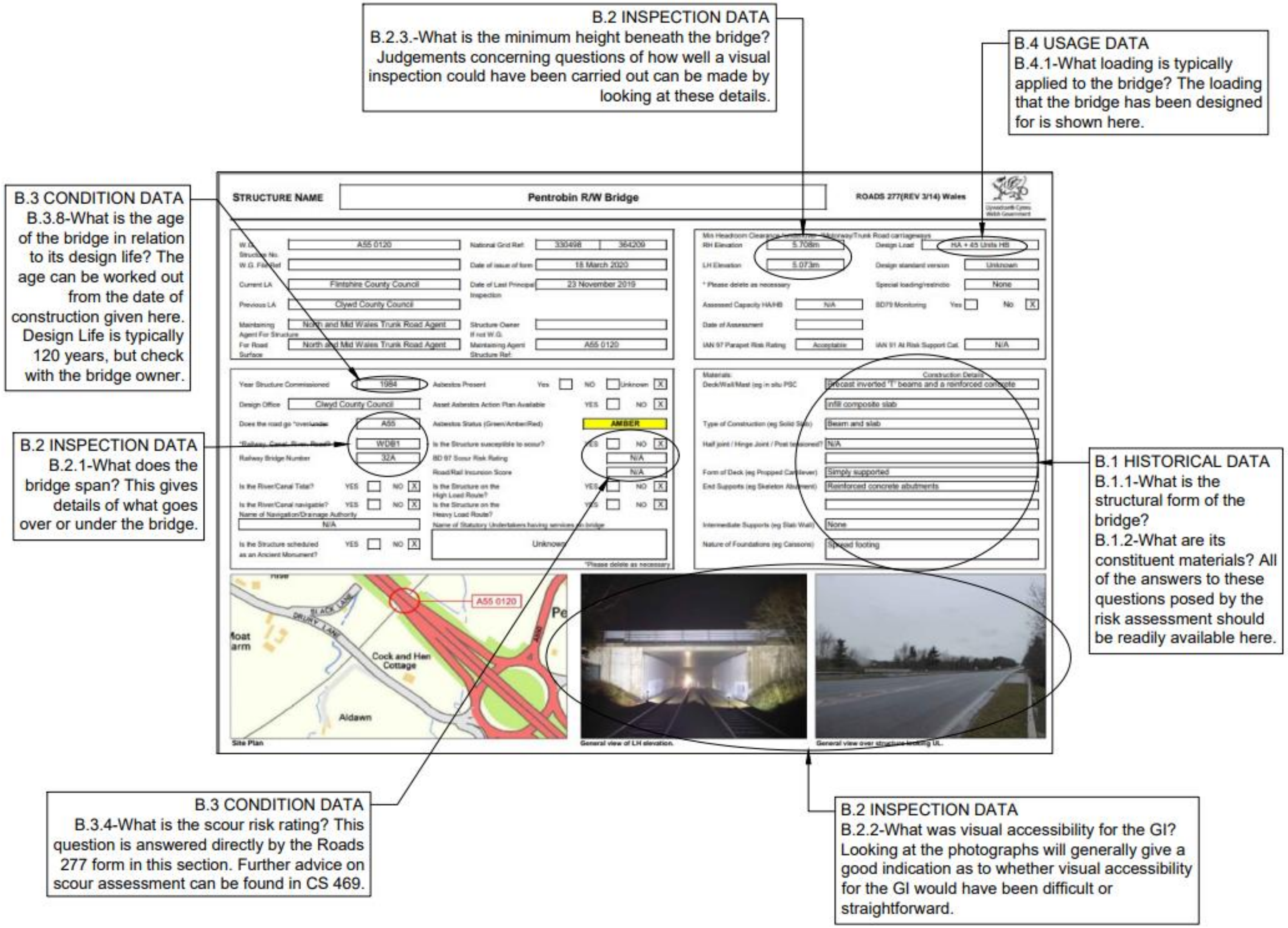
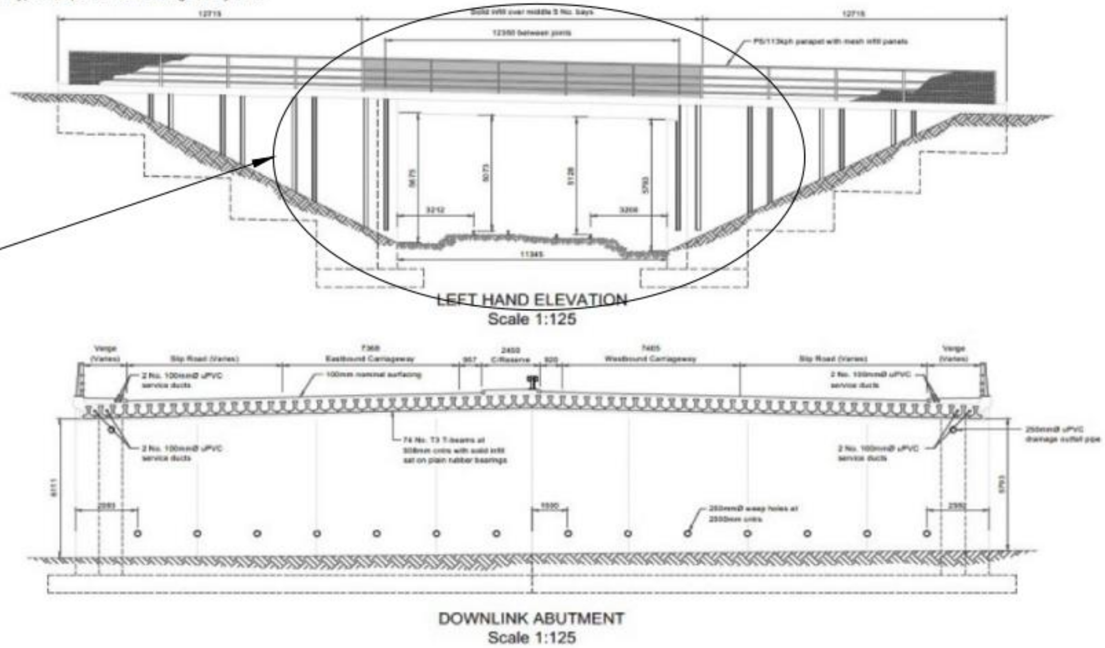


Figure 4 Using the Form Roads 277 to risk assess single-span bridges (1 of 2)

B.2 INSPECTION DATA
B.2.4-What is the span of the bridge? Is it less than 10m, between 10 and 25m or greater than 25m? All major dimensional requirements can be obtained from drawing on Page 2 of the Roads 277.

Dimensional Elevation, Cross Section and Components of Structure. **ROADS 277(REV 3/14) Wales**

Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)
Indicate type and position of bearings and joints.



		Manufacturer	Type
Prestressing System		N/A	N/A
Paint System:	Parapet	N/A	N/A
	Internal	N/A	N/A
	External	N/A	N/A

	Manufacturer	Type	Position
Bearings*	PSC	Rubber	Ends of beams
Joints*	Expandite	DF6	Ends of deck
Parapets	Lindley	P2 - 113Kph	Both sides
Waterproofing	Expandite	Famguard	Deck

*Indicate on sketch above

Figure 5 Using the Form Roads 277 to risk assess single-span bridges (2 of 2)

7.1.7. Using the Inspection Pro Forma – Single-Span Bridges

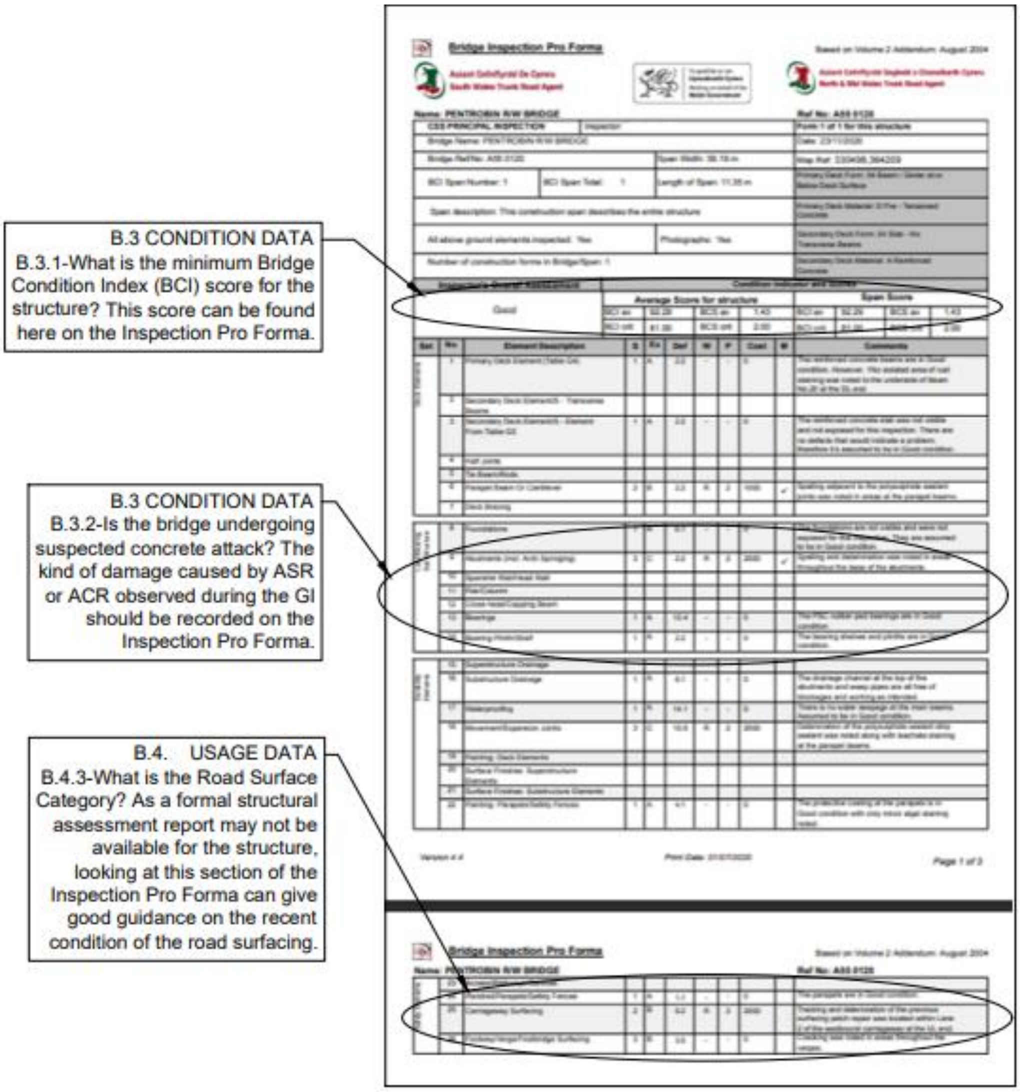


Figure 6 Using the Inspection Pro-Forma to risk assess single-span bridges

8. C - Multi-Span Bridges

Multi-span bridges will often be the largest of the five structural types being risk assessed. These bridges are multi-span because they need to cross large obstacles such as rivers and motorways. The main difference, therefore, between the multi-span bridge risk assessment and the single-span bridge risk assessment is accounting for differences in articulation and overcoming difficulties in getting a good visual inspection.

8.1. Multi-Span Bridge Questionnaire

All questions capable of being answered by directly taking information from an Inspection Pro Forma or Form Roads 277 are illustrated in Figures 7 to 9 below. Other questions, which may not have direct answers in either of these forms, are described below. The advice given on these subjects may be used for all other structural types, not just for bridges. Any questions not addressed here will be addressed within the Culverts and Single Span Bridges sections.

8.1.1. Question C.1.3. What is the articulation of the bridge?

Bridge articulation affects the risk of deterioration. As with single-span bridges the main thing to consider is historical performance. Secondly, the degree of redundancy associated with various bridge articulations is also worth consideration. The rationale behind each of the various bridge articulations chosen is illustrated in Table 11 below:

Articulation	**Rationale**
Integral on bankseats	No bearings or joints mean enhanced durability. This articulation requires multiple failures and has a slow, progressive deterioration mechanism.
Integral on full height abutments	No bearings or joints mean enhanced durability. This articulation requires multiple failures and has slow, progressive deterioration. This type currently has greater unpredictability due to complex soil – abutment interaction.
Continuous	Minimal joints mean enhanced durability. Failure requires deterioration in more than one span and in multiple areas.
Simply supported spans	Many joints and bearings mean more durability issues. Each span is, in effect, a separate structure, so a 3-span bridge is 3 single-span bridges, with all the potential problems that accompany it.
Half joint / hinged decks	Historical performance demonstrates that half-joint and hinge bridge decks can cause problems. A special investigation should have been done. If not, one will be needed and an ongoing management strategy determined.

Table 11 - Bridge articulation

8.1.2. Question C.2.2. What was access for the GI?

The level of access for a GI gives an indication on the reliability of the inspection information gathered. If access is limited, the GI may not pick up and record defects which exist but are not easily visible, thus reducing the reliability of the GI. The rationale for the choices of GI access is shown in Table 12 below:

Access	Rationale
Confined and difficult	Confined and difficult should be selected If access is difficult resulting in very little of the structure being visible at GI.
Poor access to one or more pier(s) / abutments	Poor access should be selected if critical elements are not visible during the GI.
Good access to one or more pier(s) / abutments	Good access should be selected if access allows good visibility to one or more pier(s) / abutments.
Full access to all spans	Full access should be selected if there is good visibility to all parts of the structure.

Table 12 - Multi Span Bridge GI Access

8.1.3. Question C.2.4. What level of access is there to the bridge spans?

The level of access afforded for the general inspection gives an indication of how well the inspector could see the various bridge elements and subsequently gives an idea of the reliability of the inspection. If all spans are fully accessible, this suggests that the inspector had good visibility of the whole structure and therefore the GI will be comprehensive and will have captured all the defects. However, if the structure is inaccessible or only parts of it are accessible then the visibility will be limited and there may be defects present which cannot be observed. The maximum height of the structure is also relevant here as defects are not easily visible on the high elements of very tall structures.

8.1.4. Using the Roads 277 – Multi-Span Bridges

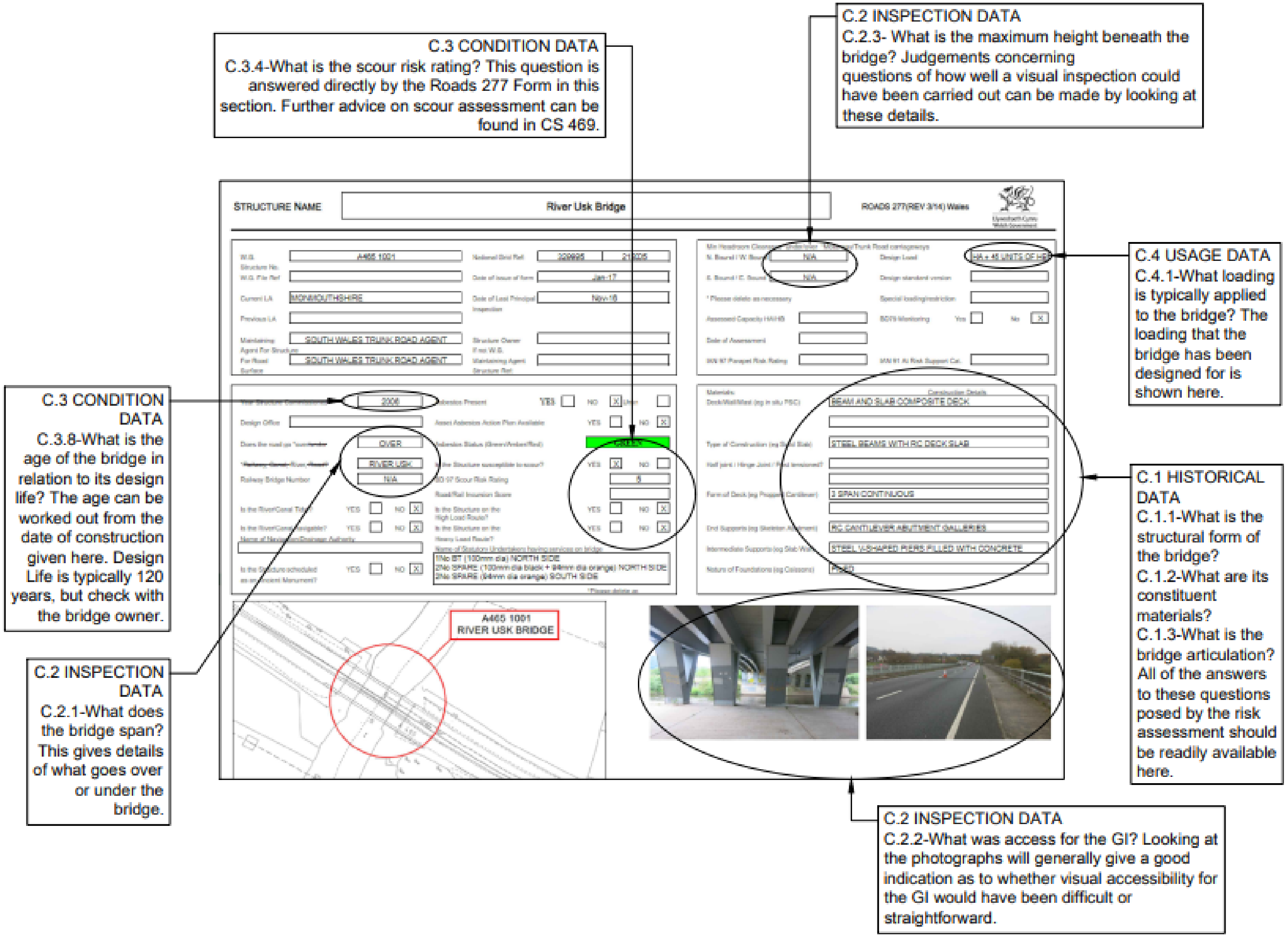


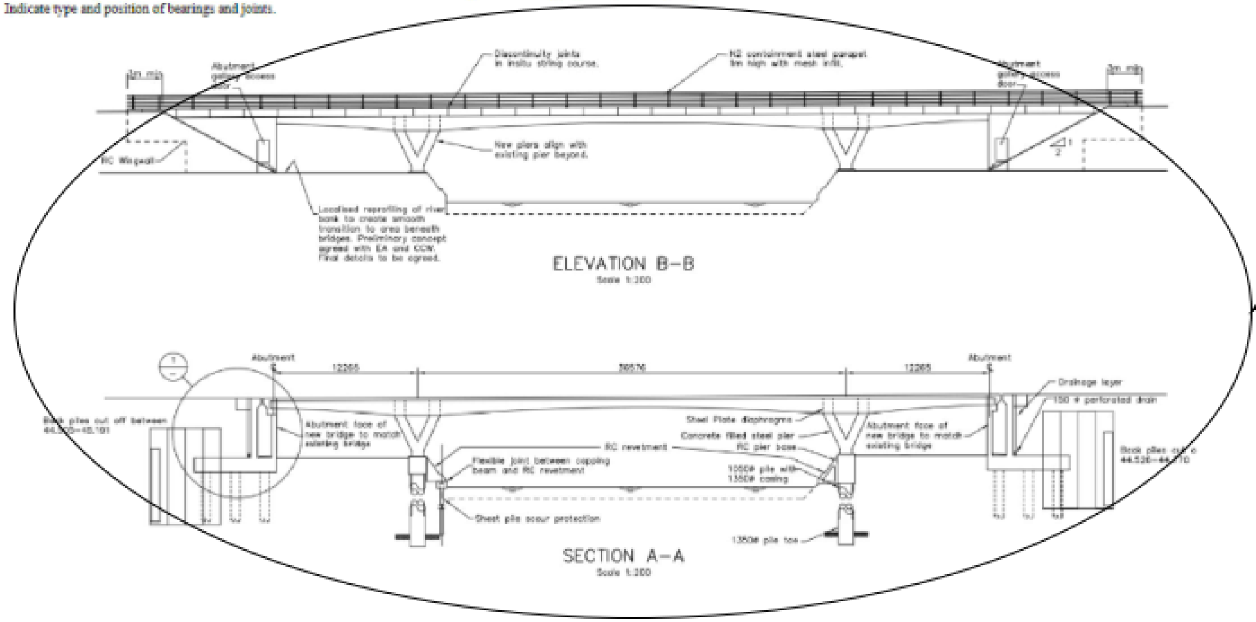
Figure 7 Using the Form Roads 277 to risk assess multi-span bridges (1 of 2)

Dimensional Elevation, Cross Section and Components of Structure. **ROADS 277(REV 3/14) Wales**

Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.

Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)

Indicate type and position of bearings and joints.



C.2 INSPECTION DATA
C.2.4-What level of access is there to individual bridge spans? How difficult or easy it was for the Inspecting Engineer to visualise elements of the bridge can be seen from the drawings on the 277 form.

		Manufacturer	Type
Prestressing System			
Paint System:	Parapet	Leigh Paints	156-121-121-188 18C33 2No stripe coats where req'd
	Internal		
	External		

	Manufacturer	Type	Position
Bearings*	N/A		
Joints*	PITCHMASTIC	ASPHALTIC PLUG	
Parapets	P&R ENGINEERING (MIDLANDS)	CORUS HBP 200	
	P&R ENGINEERING (MIDLANDS)	CORUS P4 1150mm	
Waterproofing	BAYER PLC	PmB BRIDGEDECK	

*Indicate on sketch above

Figure 8 Using the Form Roads 277 to risk assess multi-span bridges (2 of 2)

8.1.5. Using the Inspection Pro Forma – Multi-Span Bridges

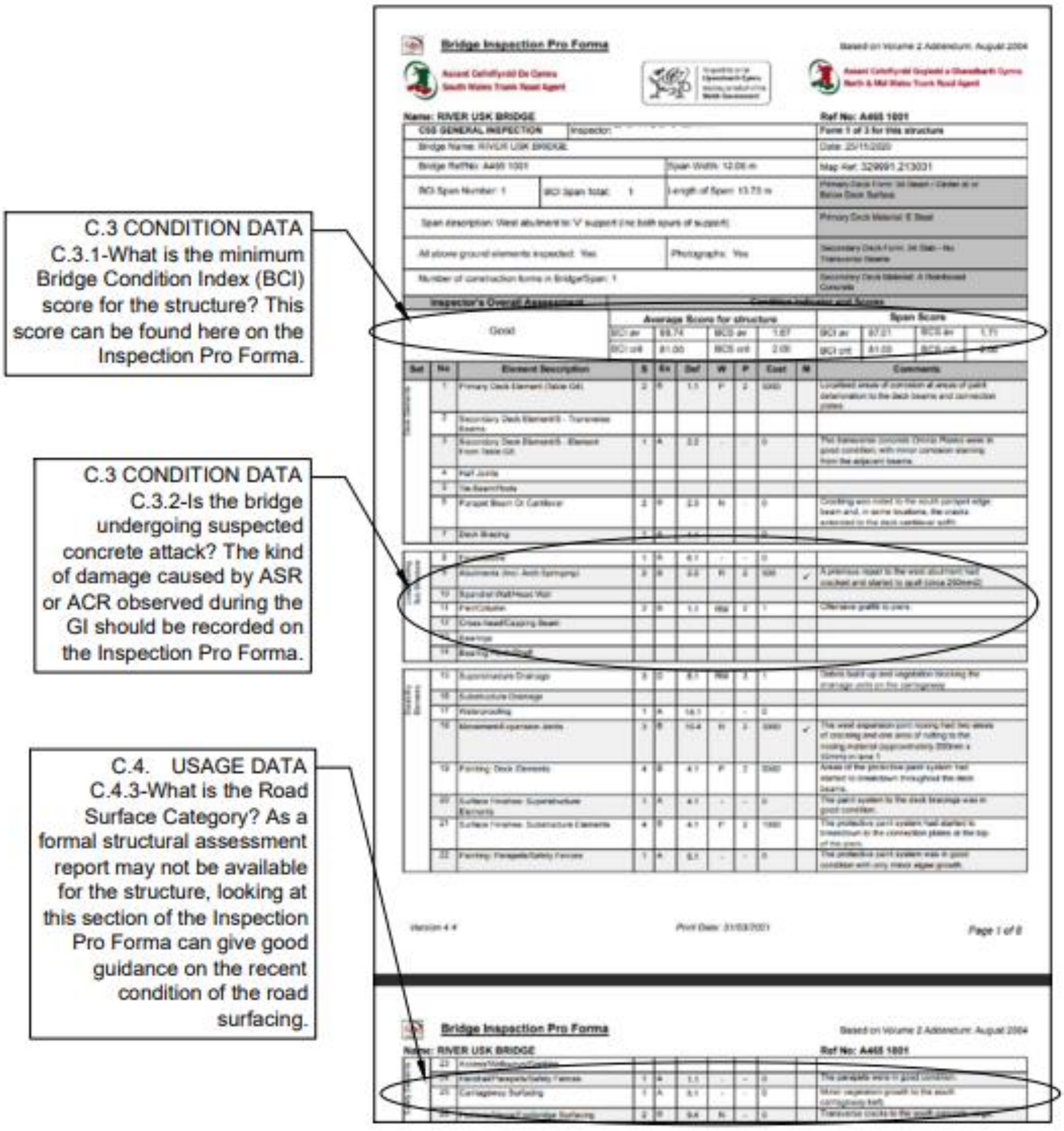


Figure 9 Using the Inspection Pro-Forma to risk assess multi-span bridges

9. D - Footbridges / Gantries

Footbridges are generally lighter weight bridges designed to carry only pedestrians, cyclists and equestrians. Gantries are typically constructed on motorways and heavier trafficked roads and can be portal or cantilever structures used to carry various types of signs and M+E equipment.

9.1. Footbridge / Gantries Questionnaire

All questions not illustrated by the following Figures 10 to 12 or described below will be described in the previous sections on culverts, single span bridges and multi span bridges.

9.1.1. Question D.2.4. What level of access is there to the structure spans?

The level of access for a GI gives an indication on the reliability of the inspection information gathered. If access is limited, the GI may not pick up and record defects which exist but are not easily visible, thus reducing the reliability of the GI. The rationale of the choices for the level of access is shown in Table 13 below:

Access	Rationale
Confined and difficult	Confined and difficult should be selected if access is difficult resulting in very little of the structure being visible at GI.
Good access to supports	Select this option if good access is available to the supports only.
Full access to all spans	Full access should be selected if there is good visibility to all parts of the structure.
Good access to some supports and poor access to others	Select this option if good access is afforded to only part of the structure during the GI.

Table 13 - Level of Access

9.1.2. Using the Form Roads 277 – Footbridges / Gantries

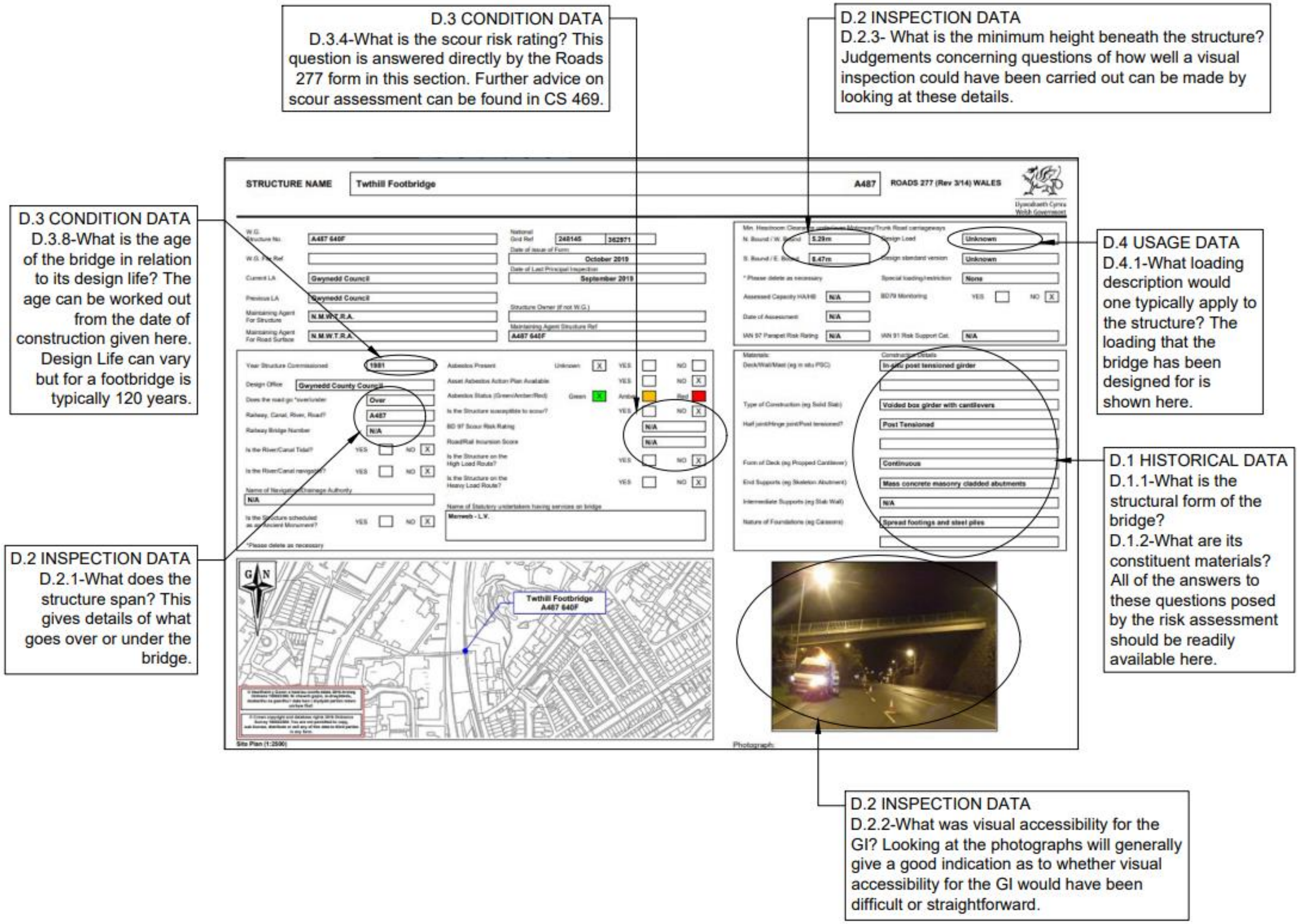
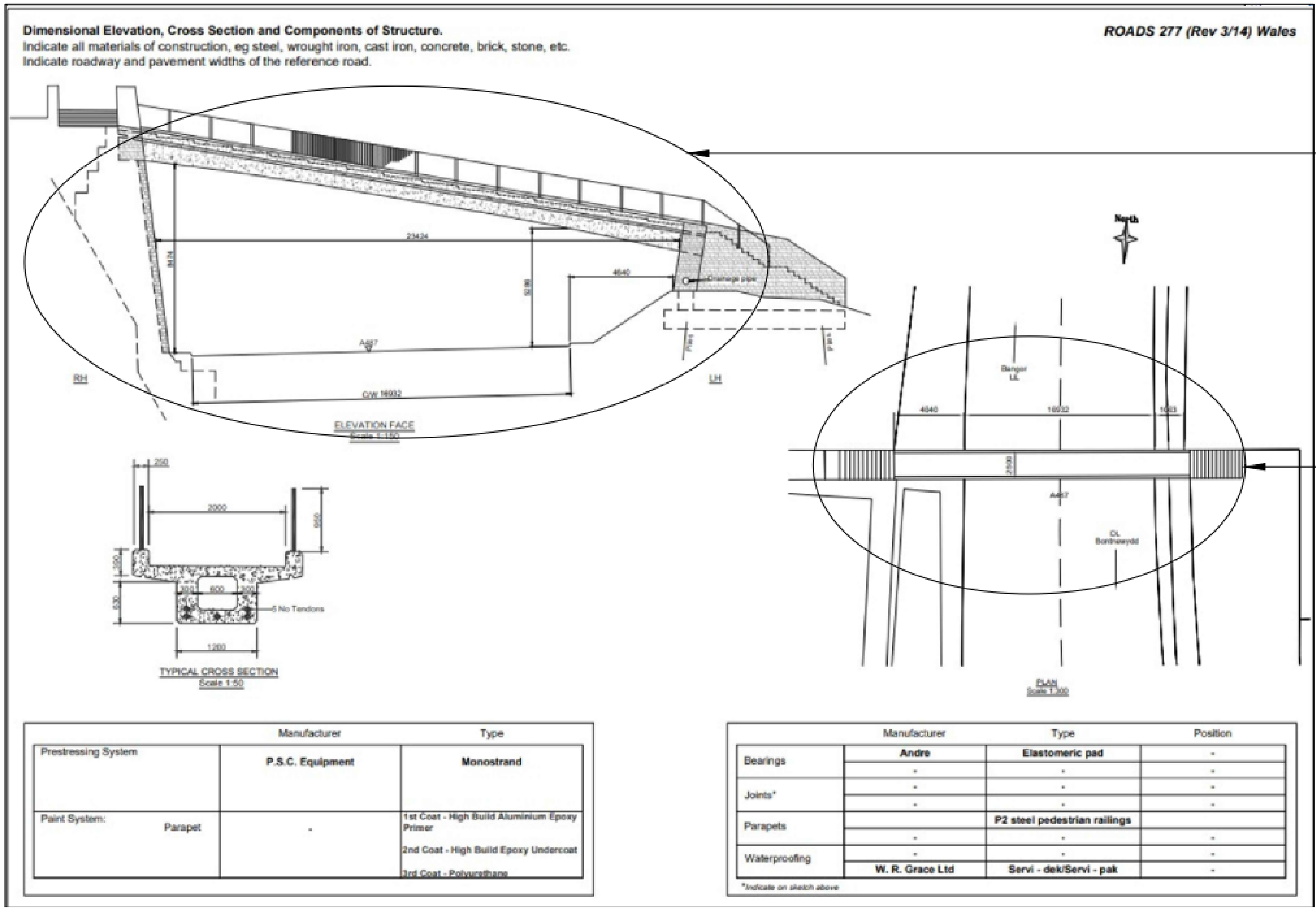


Figure 5 Using the Form Roads 277 to risk assess footbridges or gantries (1 of 2)



	Manufacturer	Type
Prestressing System	P.S.C. Equipment	Monostrand
Paint System: Parapet	-	1st Coat - High Build Aluminium Epoxy Primer 2nd Coat - High Build Epoxy Undercoat 3rd Coat - Polyurethane

	Manufacturer	Type	Position
Bearings	Andre	Elastomeric pad	-
	-	-	-
Joints*	-	-	-
	-	-	-
Parapets		P2 steel pedestrian railings	
	-	-	-
Waterproofing	-	-	-
	W. R. Grace Ltd	Servi - dek/Servi - pak	-

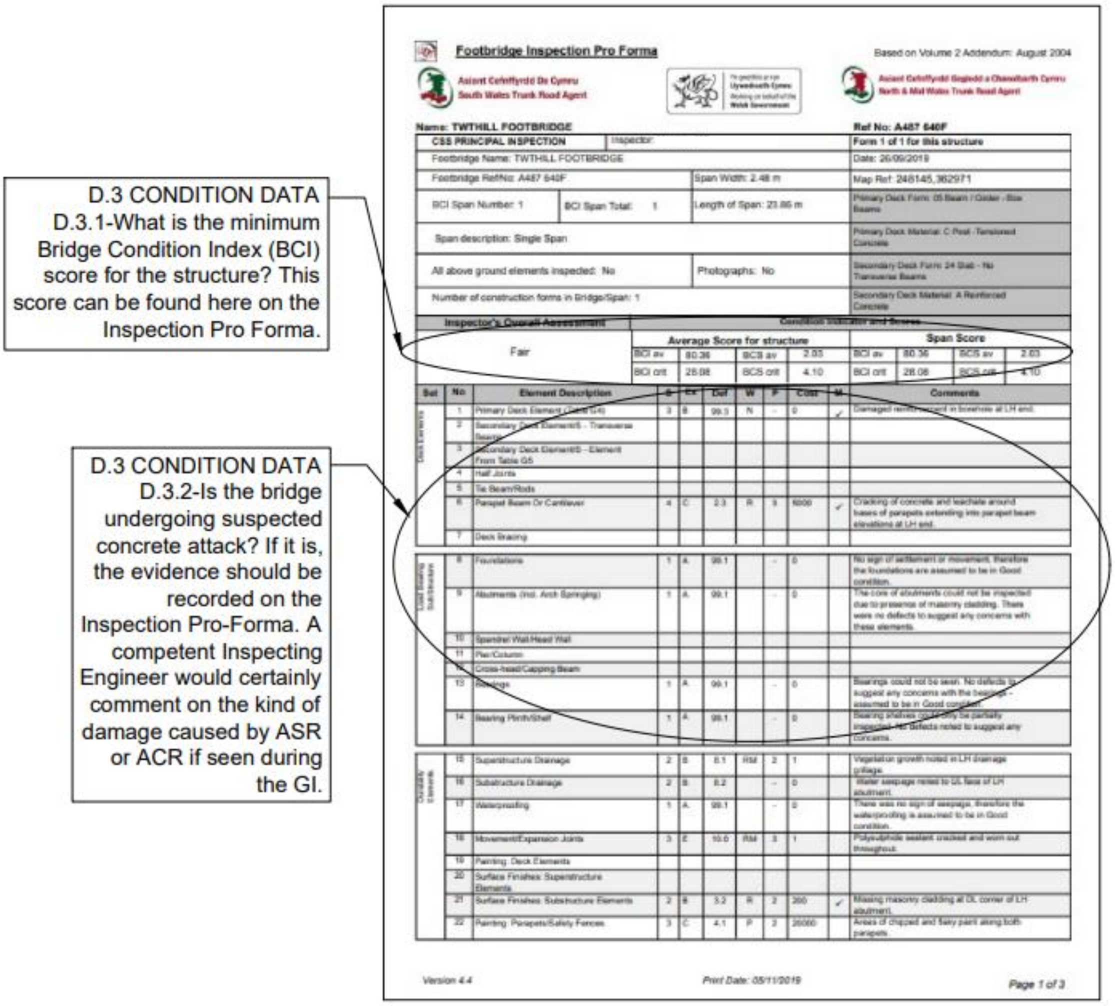
*Indicate on sketch above

D.2 INSPECTION DATA
D.2.4-What level of access is there to the structure spans? How difficult or easy it was for the Inspecting Engineer to view elements of the bridge can be seen from the drawings on the 277 form.

D.4 USAGE DATA
D.4.1-What loading description would one typically apply to the structure? Looking at the plan, elevation and location etc can tell us a lot about whether the footbridge has heavy usage. Is it affected by wind and does it have solid elements in elevation? Was it designed for equestrian use, or is it prone to vandalism?

Figure 11 Using the Form Roads 277 to risk assess footbridges or gantries (2 of 2)

9.1.3. Using the Inspection Pro Forma – Footbridges / Gantries



Footbridge Inspection Pro Forma

Based on Volume 2 Addendum: August 2004

Asiant Cefnffyrdd De Cymru South Wales Trunk Road Agent

Llywodraeth Cymru Welsh Government

Asiant Cefnffyrdd Gogledd a Chanolbarth Cymru North & Mid Wales Trunk Road Agent

Name: TWTHILL FOOTBRIDGE **Ref No: A487 640F**

CSS PRINCIPAL INSPECTION	Inspector:		**Form 1 of 1 for this structure**
Footbridge Name: TWTHILL FOOTBRIDGE			Date: 26/09/2019
Footbridge Ref/No: A487 640F		Span Width: 2.48 m	Map Ref: 248145,362971
BCI Span Number: 1	BCI Span Total: 1	Length of Span: 23.86 m	Primary Deck Form: 05 Beam / Girder - Box Beams
Span description: Single Span			Primary Deck Material: C Post - Tensioned Concrete
All above ground elements inspected: No		Photographs: No	Secondary Deck Form: 24 Slab - No Transverse Beams
Number of construction forms in Bridge/Span: 1			Secondary Deck Material: A Reinforced Concrete

Inspector's Overall Assessment	Condition Indicator and Scores							
	Average Score for structure				Span Score			
Fair	BCI av	80.36	BCS av	2.03	BCI av	80.36	BCS av	2.03
	BCI crit	28.08	BCS crit	4.10	BCI crit	28.08	BCS crit	4.10

Set	No	Element Description	S	Ex	Def	W	P	Cost	M	Comments
Deck Elements	1	Primary Deck Element (Table G4)	3	B	99.3	N	-	0	✓	Damaged reinforcement in borehole at LH end.
	2	Secondary Deck Element/S - Transverse Beams								
	3	Secondary Deck Element/S - Element From Table G5								
	4	Half Joints								
	5	Tie Beam/Rods								
	6	Parapet Beam Or Cantilever	4	C	2.3	R	3	6000	✓	Cracking of concrete and leachate around bases of parapets extending into parapet beam elevations at LH end.
	7	Deck Bracing								
Load Bearing Substructure	8	Foundations	1	A	99.1		-	0		No sign of settlement or movement, therefore the foundations are assumed to be in Good condition.
	9	Abutments (incl. Arch Springing)	1	A	99.1		-	0		The core of abutments could not be inspected due to presence of masonry cladding. There were no defects to suggest any concerns with these elements.
	10	Spandrel Wall/Head Wall								
	11	Pier/Column								
	12	Cross-head/Capping Beam								
	13	Bearings	1	A	99.1		-	0		Bearings could not be seen. No defects to suggest any concerns with the bearings - assumed to be in Good condition.
	14	Bearing Plinth/Shelf	1	A	99.1		-	0		Bearing shelves could only be partially inspected. No defects noted to suggest any concerns.
Durability Elements	15	Superstructure Drainage	2	B	8.1	RM	2	1		Vegetation growth noted in LH drainage grillage.
	16	Substructure Drainage	2	B	8.2		-	0		Water seepage noted to GL face of LH abutment.
	17	Waterproofing	1	A	99.1		-	0		There was no sign of seepage, therefore the waterproofing is assumed to be in Good condition.
	18	Movement/Expansion Joints	3	E	10.6	RM	3	1		Polysulphide sealant cracked and worn out throughout.
	19	Painting: Deck Elements								
	20	Surface Finishes: Superstructure Elements								
	21	Surface Finishes: Substructure Elements	2	B	3.2	R	2	300	✓	Missing masonry cladding at DL corner of LH abutment.
	22	Painting: Parapets/Safety Fences	3	C	4.1	P	2	20000		Areas of chipped and flaky paint along both parapets.

Version 4.4 Print Date: 05/11/2019 Page 1 of 3

Figure 6 Using the Inspection Pro-Forma to risk assess footbridges or gantries

10. E - Retaining Walls

Retaining walls are structures built to resist the lateral pressure of soil, to maintain a change in level of the ground which could not be achieved naturally.

10.1. Retaining Walls Questionnaire

All questions not illustrated by the following Figures 13 to 15 or described below will be described in the previous sections on culverts, single span bridges and multi span bridges.

10.1.1. Question E.1.1. What is the Structural Form?

The rationale behind many of the structural forms chosen is illustrated in Table 14 below:

Structural Form	**Rationale**
Gravity	Includes mass concrete, gabion and crib retaining walls where these walls typically have a shorter retained height relative to other retaining wall types.
Cantilevered	These walls can have a larger retained height but use comparatively less material compared to gravity walls, where careful design and construction is required.
Embedded	Includes sheet pile retaining walls, reinforced concrete pile walls, secant pile walls and contiguous piled walls.
Soil Nails	Typically use steel bars grouted in place to stabilise or retain a soil mass. The slope may then be faced with reinforced concrete or high tensile steel mesh.
Revetement	Includes any sloping structure built to protect embankments or shorelines.
Dry Stone	This is a type of gravity retaining wall built from stones without mortar.
Rock Anchors	Rock anchors default to an automatic 6-year PI interval.
Other	Other can be selected for a combination of different soil retention measures or if the type of structure is unknown.

Table 14 - Retaining Wall Structural Form

10.1.2. Question E.1.2. What is the constituent material?

The rationale behind the constituent materials of retaining walls is shown in Table 15 below:

Constituent Material	**Rationale**
Reinforced Concrete	Typically used for cantilever retaining walls.
Steel	Typically used for embedded retaining walls.
Masonry	Typically either gravity or dry stone retaining walls if no mortar is used.
Gabion	Gravity retaining walls.

Reinforced Earth	Typically used where the space available does not necessitate a vertical wall.
Soil Nails	Typically used to ensure slope stability.
Mass Concrete	Typically used for gravity retaining walls.
Other	Other can be selected if a combination of different soil retention measures has been used or if the constituent material is unknown.

Table 15 - Retaining Wall Constituent Material

10.1.3. Question E.2.1. What is the retaining wall adjacent to?

Adjacent land properties refer to land either above or below the retaining wall, which can be hugely influential in both the *likelihood* of deterioration and the *consequence* of failure. They affect risk both indirectly and directly. Indirectly, they can limit access and make it difficult to view the structure. This can compromise the quality of the inspection data obtained, and therefore the validity of the input of the risk assessment. Directly, they influence risk by bringing *consequence* into the equation. The adjacent land property largely determines what the consequences of failure will be. Adding further to the equation is the ability of the adjacent land property to affect the *likelihood* of the structure deteriorating. The rationale behind the risk assessment, based on these influencing factors, is given below in Table 16:

Adjacent Land Property	**Rationale**
Water	When water is the adjacent land property: - Limited access often for the GI; - Damp conditions/foundations affect decay; - Changes in water level incur cyclical loads; - Small fractures made worse by water ingress -Scour or erosion can adversely affect the structure.
Railway	When a railway is the adjacent land property: - There is often limited access for the GI; - Consequences of failure could affect an operational railway.
Classified road / public space or area	When a classified road is the adjacent land property: - Probably good visual access for the GI; - Consequences of failure could be severe; - High speed roads present greater risks to operational personnel; - Greater disruption caused by failure.
Field / unclassified road or track	When a field or unclassified road is the adjacent land property: - Probably good visual access for the GI; - Consequences of failure are less severe; - Typical speed limit of 40mph and medium to low traffic counts present minimal risks to operational personnel; - Minimal disruption caused by failure.

Table 16 - Adjacent land options

10.1.4. Questions E.2.2. What was access for the GI? and E.2.3. What is the maximum retained height?

Answers to both these questions can be answered from page 2 of the Form Roads 277 which will typically show a cross section of the retaining wall identifying how access was possible during the GI and the retained height.

10.1.5. Question E.3.7. Has the retaining wall been assessed, and if so, what is its assessed capacity to current standards?

Structural assessments of retaining walls will often be qualitative, due to much of the structure being buried and a lack of as-built information. Table 17 below explains the risk assessment options.

Type of Assessment	Rationale
Yes – Qualitative	This indicates that a thorough qualitative assessment has been done and found the wall to be fully capable.
Yes – Quantitative	For newer, larger walls, it is more likely that an 'assessment by calculation' has been done. This should define the wall's capability and fitness for purpose.
No or Don't know	Either no assessment has been carried out or there is uncertainty whether an assessment has been completed.
Assessment not required	The wall may be on such a small scale that it does not need to be assessed or is a new structure.
CS 470 monitoring programme	Post-assessment the wall has been found to be sub-standard and is now being actively managed.

Table 17 - Retaining wall types of assessment

10.1.6. Question E.4.1. What loading is typically applied to the structure?

Transient live loads can affect retaining walls in different ways. The most obvious way is from HA live load surcharge transferring vertical and horizontal loads against the back of the wall through the retained soil. In the context of risk, however, there are other scenarios such as vehicular impact which need to be considered. When assessing this risk, a distinction is made as to what constitutes ‘close proximity’, a dimension relative to the size of structure. For the purposes of this risk assessment, a dimension of H/2 was chosen, where H is the total height of the wall being assessed. The rationale for the choice of loading typically applied to the structure is shown in Table 18 below:

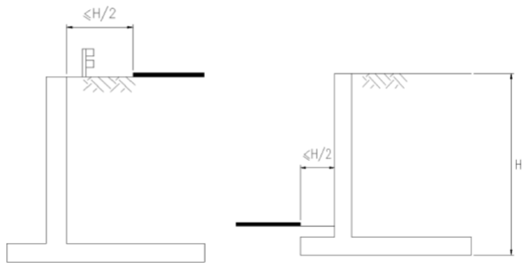
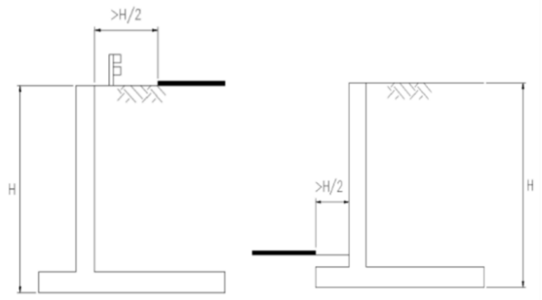
Loading	**Rationale**
HA live load near the structure (within H/2) 	For the purpose of this risk assessment, the exertion of live loading above or below top of wall level has the same effect. The risk of damage or deterioration clearly increases as the proximity of live loading increases. The type of loading applied makes no difference. It could be surcharge (from above), or vehicular impact (from below). The risk remains broadly the same.
HA live load distant from the structure (further than H/2) 	The distance that constitutes ‘close proximity’, in the context of this risk assessment, is H/2, where H is the total height of the wall. If live loading is present at a distance inside H/2, then the risk is deemed to be greater than if it is present outside H/2.

Table 18 - Retaining wall loading

10.1.7. Using the Form Roads 277 – Retaining Walls

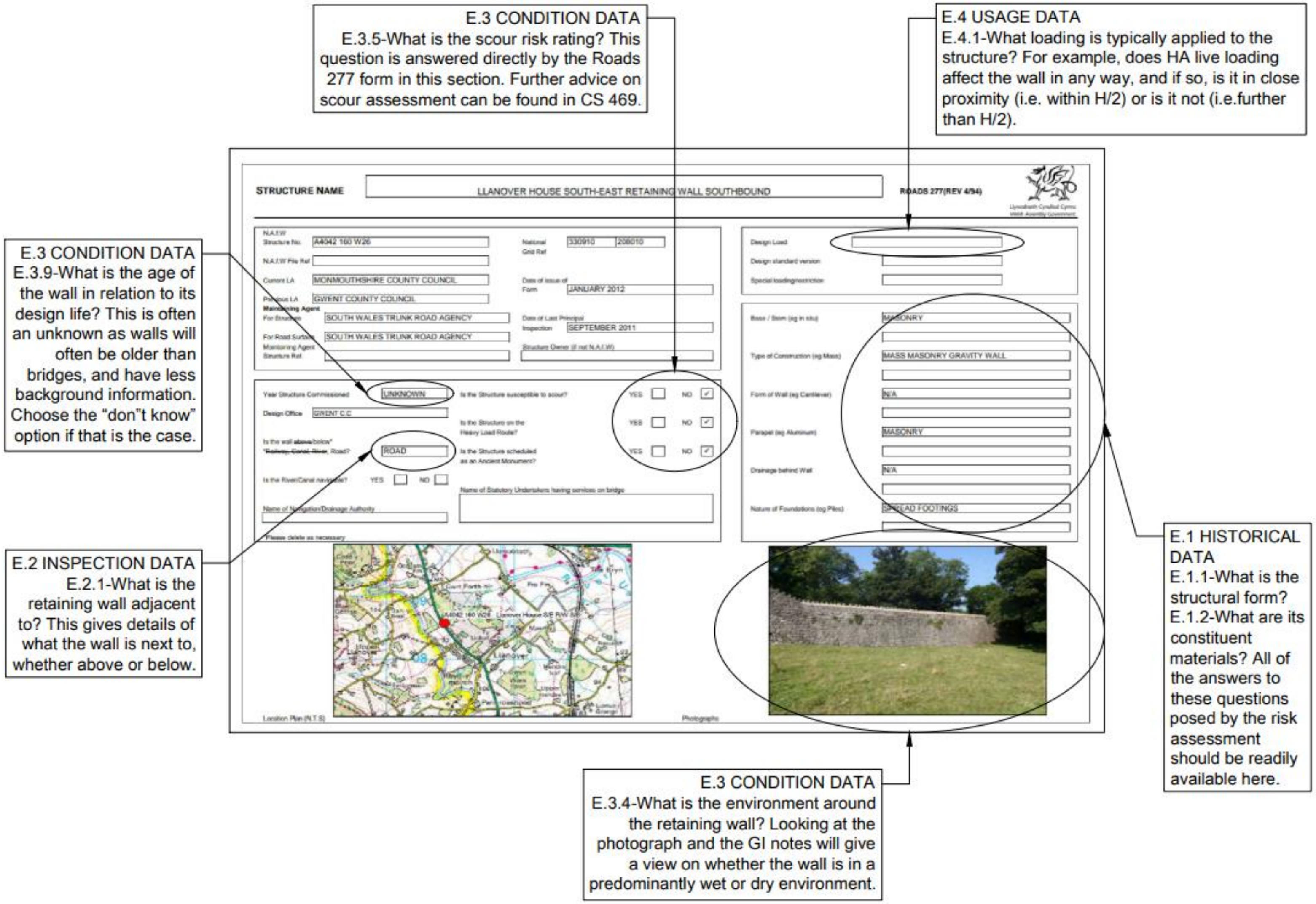
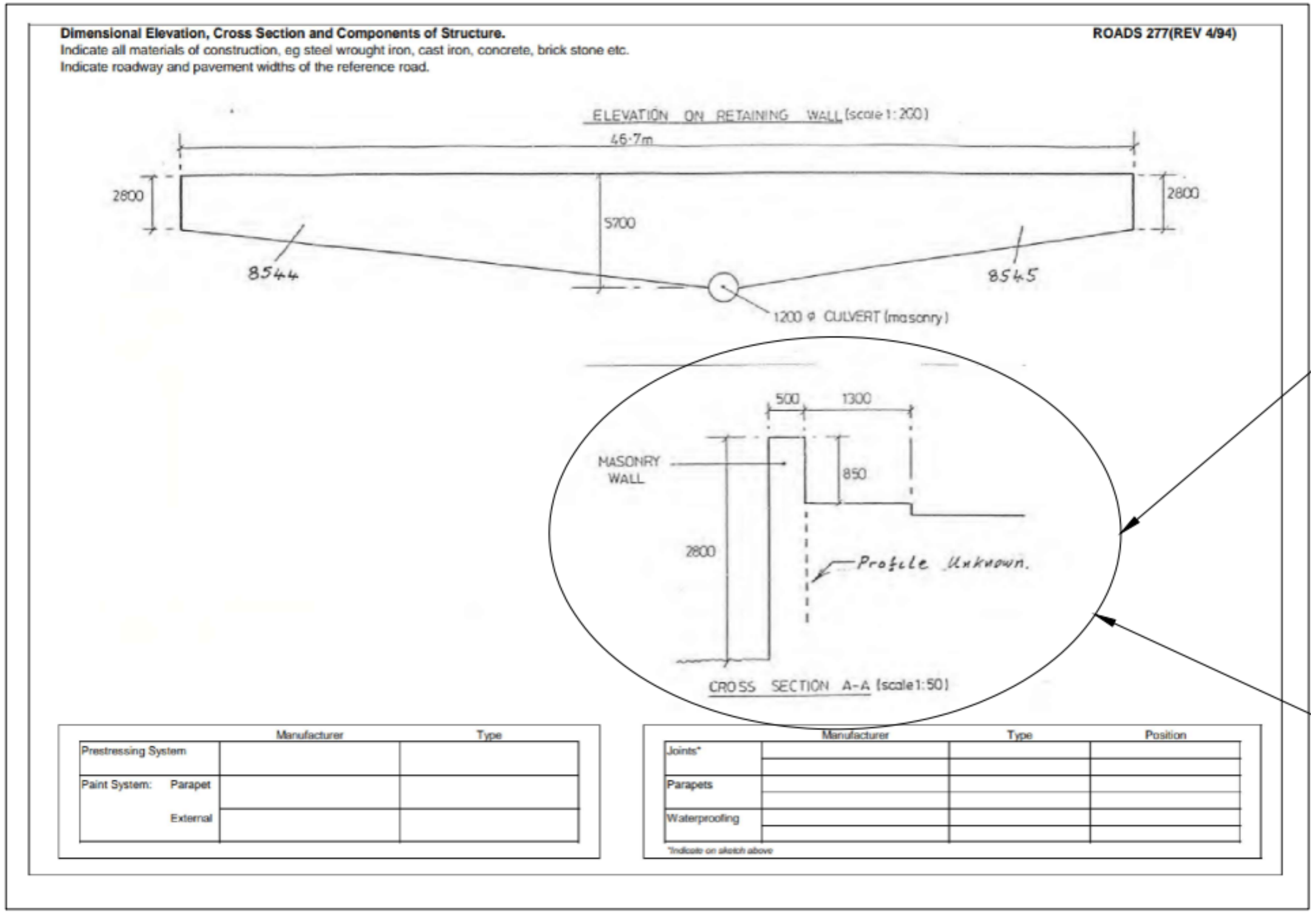


Figure 13 Using the Form Roads 277 to risk assess retaining walls (1 of 2)

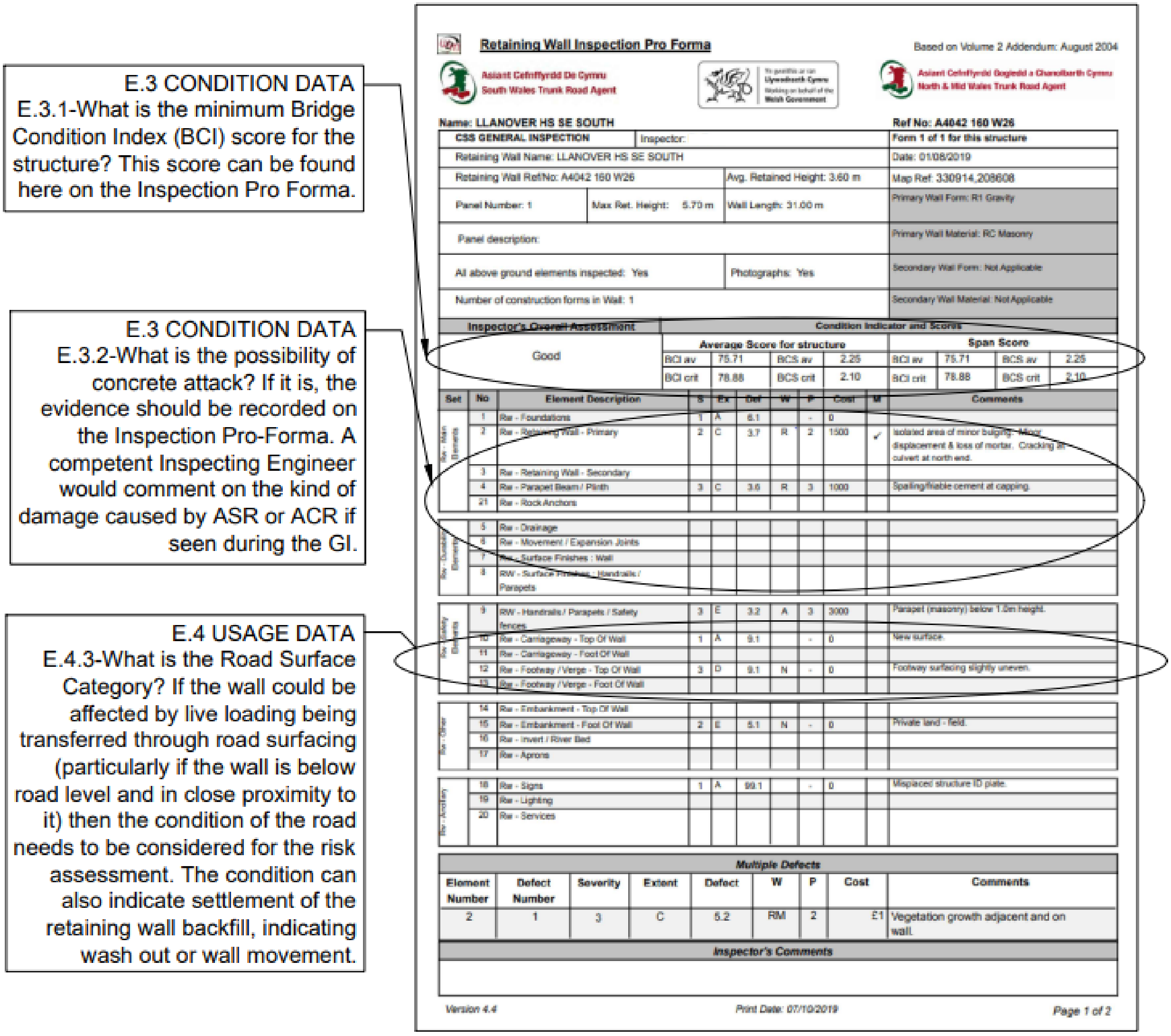


E.2 INSPECTION DATA
E.2.2-What was access for the GI? Is it to the top of the wall, or to the base of the wall, or to both? The answer to this question should become clear from the section drawing, and clarify how possible it was to access the wall during GI.

E.2 INSPECTION DATA
E.2.3-What is the maximum retained height? This should become clear using either the dimensions on the elevation or section contained on the Roads 277 form.

Figure 7 Using the Form Roads 277 to risk assess retaining walls (2 of 2)

10.1.8. Using the Inspection Pro Forma – Retaining Walls



Retaining Wall Inspection Pro Forma

Based on Volume 2 Addendum: August 2004

Asiant Cefnffyrdd De Cymru
South Wales Trunk Road Agent

Asiant Cefnffyrdd Gogledd a Chanolbarth Cymru
North & Mid Wales Trunk Road Agent

Name: LLANOVER HS SE SOUTH **Ref No: A4042 160 W26**

CSS GENERAL INSPECTION	Inspector:		Form 1 of 1 for this structure
Retaining Wall Name: LLANOVER HS SE SOUTH			Date: 01/08/2019
Retaining Wall RefNo: A4042 160 W26		Avg. Retained Height: 3.60 m	Map Ref: 330914,208608
Panel Number: 1	Max Ret. Height: 5.70 m	Wall Length: 31.00 m	Primary Wall Form: R1 Gravity
Panel description:			Primary Wall Material: RC Masonry
All above ground elements inspected: Yes		Photographs: Yes	Secondary Wall Form: Not Applicable
Number of construction forms in Wall: 1			Secondary Wall Material: Not Applicable

Inspector's Overall Assessment	Condition Indicator and Scores							
	Average Score for structure				Span Score			
Good	BCI av	75.71	BCS av	2.25	BCI av	75.71	BCS av	2.25
	BCI crit	78.88	BCS crit	2.10	BCI crit	78.88	BCS crit	2.10

Set	No	Element Description	S	Ex	Def	W	P	Cost	M	Comments
Rw - Main Elements	1	Rw - Foundations	1	A	6.1		-	0		
	2	Rw - Retaining Wall - Primary	2	C	3.7	R	2	1500	✓	Isolated area of minor bulging. Minor displacement & loss of mortar. Cracking at culvert at north end.
	3	Rw - Retaining Wall - Secondary								
	4	Rw - Parapet Beam / Plinth	3	C	3.6	R	3	1000		Spalling/friable cement at capping.
	21	Rw - Rock Anchors								
Rw - Durability Elements	5	Rw - Drainage								
	6	Rw - Movement / Expansion Joints								
	7	Rw - Surface Finishes : Wall								
	8	RW - Surface Finishes : Handrails / Parapets								
Rw - Safety Elements	9	RW - Handrails / Parapets / Safety fences	3	E	3.2	A	3	3000		Parapet (masonry) below 1.0m height.
	10	Rw - Carriageway - Top Of Wall	1	A	9.1		-	0		New surface.
	11	Rw - Carriageway - Foot Of Wall								
	12	Rw - Footway / Verge - Top Of Wall	3	D	9.1	N	-	0		Footway surfacing slightly uneven.
	13	Rw - Footway / Verge - Foot Of Wall								
Rw - Other	14	Rw - Embankment - Top Of Wall								
	15	Rw - Embankment - Foot Of Wall	2	E	5.1	N	-	0		Private land - field.
	16	Rw - Invert / River Bed								
	17	Rw - Aprons								
Rw - Ancillary	18	Rw - Signs	1	A	99.1		-	0		Misplaced structure ID plate.
	19	Rw - Lighting								
	20	Rw - Services								

Multiple Defects

Element Number	Defect Number	Severity	Extent	Defect	W	P	Cost	Comments
2	1	3	C	5.2	RM	2	£1	Vegetation growth adjacent and on wall.

Inspector's Comments

Version 4.4 Print Date: 07/10/2019 Page 1 of 2

Figure 15 Using the Inspection Pro-Forma to risk assess retaining walls

11. F - Technology Structures

Technology structures are primarily large independent Variable Message Signs (VMS) but also include larger high mast lighting columns and CCTV masts. Typically, VMS are modern structures located at key locations such as major junctions and are used to help manage the network by displaying information or advance warning to road users regarding emergencies and incidents.

11.1. Risk assessing Technology Structures

Technology structures typically have little or no redundancy and little variation in structural form, constituent materials or consequence of failure. This means that the technology structures risk assessment has fewer factors than others with only seven questions being used to gauge risk. Most of the answers to these questions should be available from the Form Roads 277, and the recent condition of the structure from the Inspection Pro-Forma in the most recent Inspection Report. Unlike the other major structural types, technology structures have a shorter design life, often sixty years, or even thirty, and consequently, sections are often thinner. Loading on technology structures is primarily dead loads and wind loads. Large fluctuations in stress can be caused by wind from alternating directions. In addition to this, vibration of the structure can amplify the damage caused. For a repeated standardised design, the lessons learnt from inspections can be applied to all similar structures. Areas where cracking has been found should be checked on all similar structures. On other structures, Principal Inspections should look at those areas where fatigue effects are more likely.

11.1.1. Question F.1.1. Is the structure a standard design (more than 10 in inspection programme)?

The structural designs are often standardised, where there will be typically more than 10 of the same design in the inspection programme. Most signs will be standard MS2, MS3 or MS4 signs which are used throughout the road network. In a few cases, the design may be bespoke. This should become clear from the structure description and photo on the Form Roads 277.

11.1.2. Question F.1.2. What is the foundation type?

Foundation types can vary for a given superstructure. Most will comprise traditional reinforced concrete piles with a pile cap or reinforced concrete spread footings. These have a proven track record, with a large data base of evidence, demonstrating them to be a robust form of substructure. More recent foundations have been constructed using helical piles or micro-piles and these newer foundation types have yet to be shown to be as robust; this is likely to change as more data becomes available. These other foundation types are used due to the buildability benefits as they are quick to install. Their unproven long-term durability means there is insufficient data available to gauge the risk, hence the lower risk score. The exact nature of the piles will become apparent from the structure description on the Form Roads 277.

11.1.3. Question F.2.1. What was access for the GI?

The drawings may show if the column has ladder access, if a walkway is provided, or if there are any other means to access the structure. If it does not, then the Form Roads 277 photographs or other inspection photographs may reveal a mode of access. If it is not clear whether the structure allows good access the “don’t know” option should be selected, and a note made to record this information at the next inspection.

11.1.4. Question F.4.1. Does the structure have fixed advance direction signs (ADS) and/or electronic signs?

The structural description, photographs and drawing details on the Form Roads 277 should make it clear whether the structure has ADS or electronic signs.

11.1.5. Using the Form Roads 277 – Technology Structures

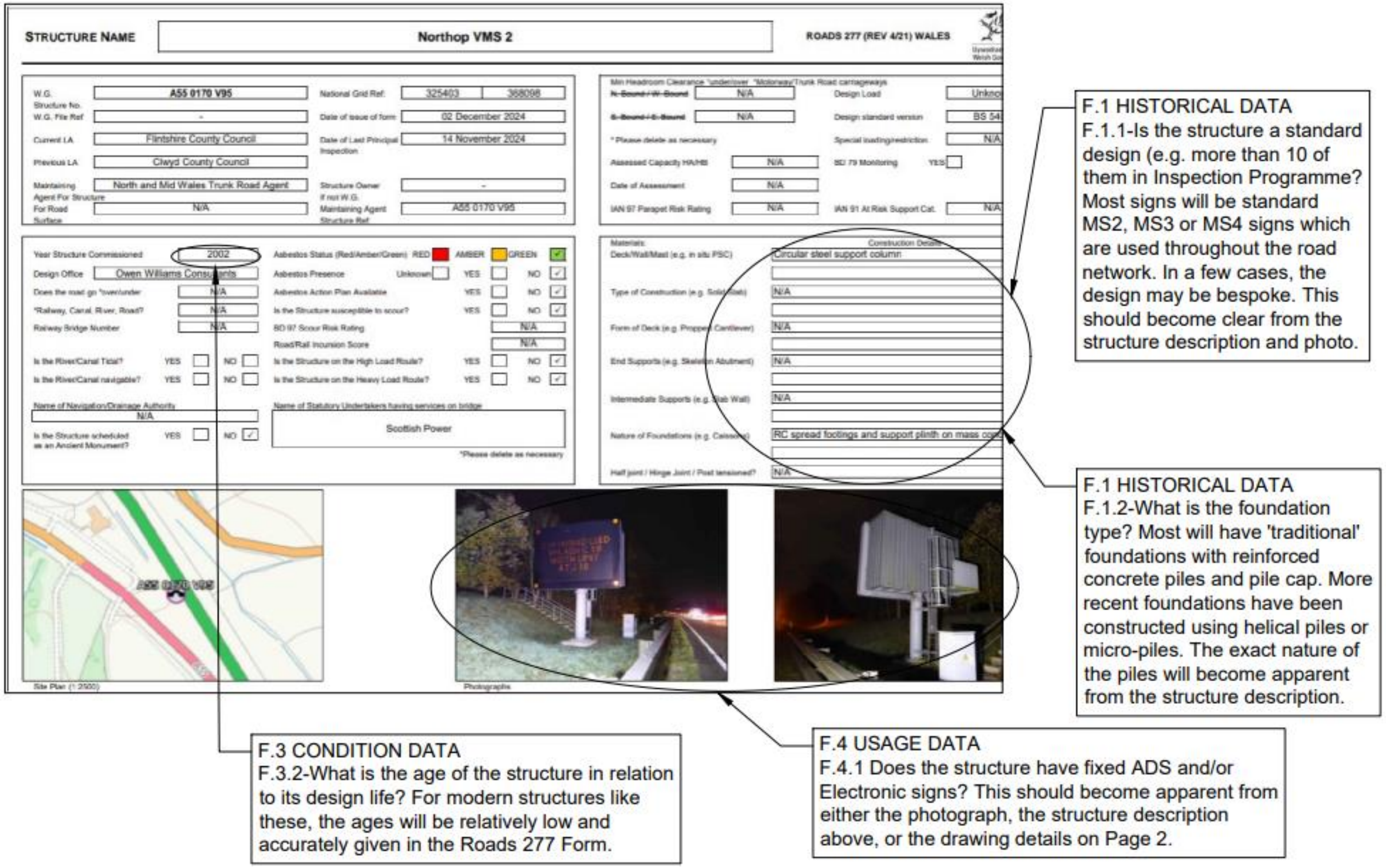
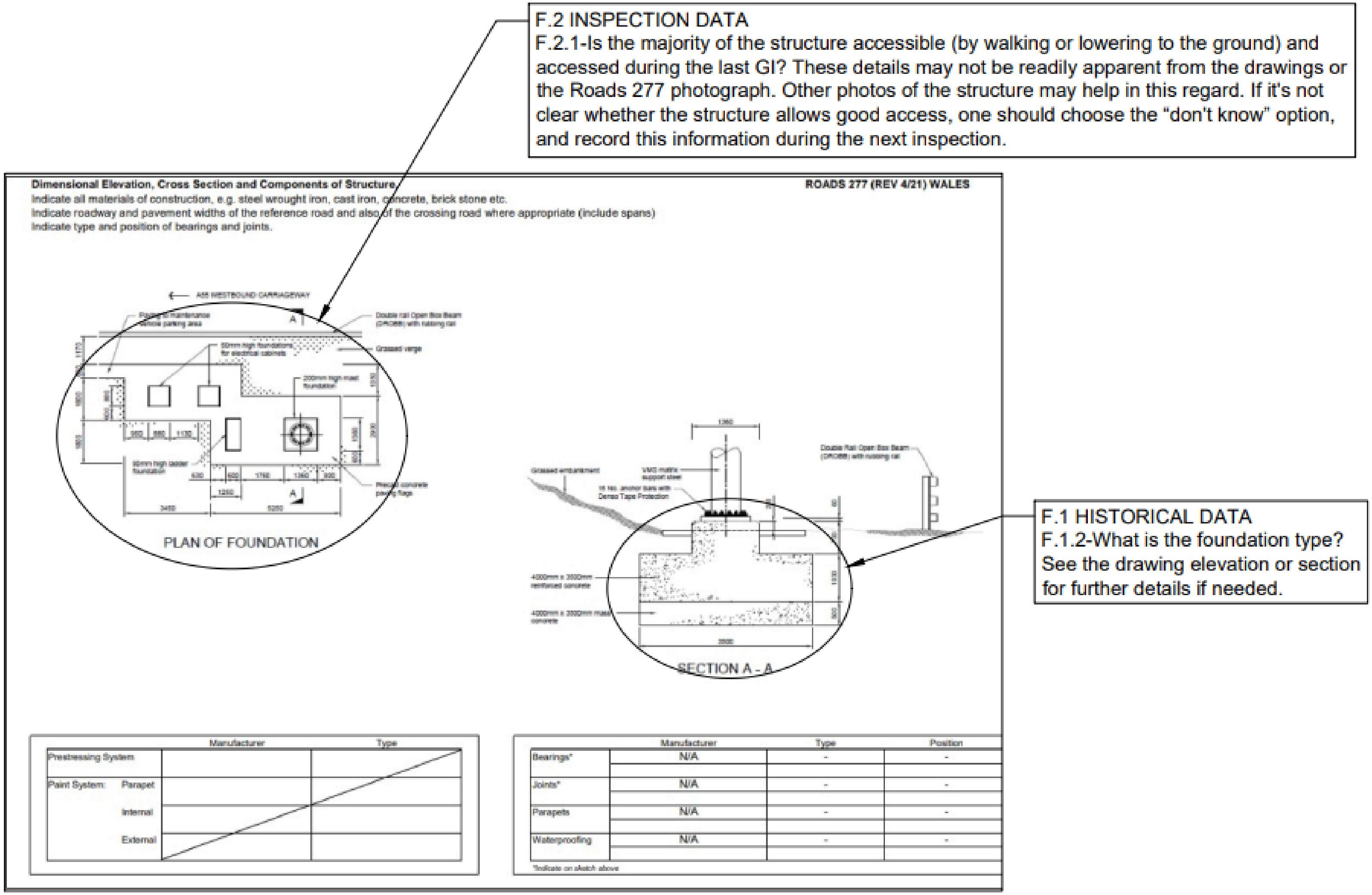


Figure 8 Using the Form Roads 277 to risk assess technology structures (1 of 2)



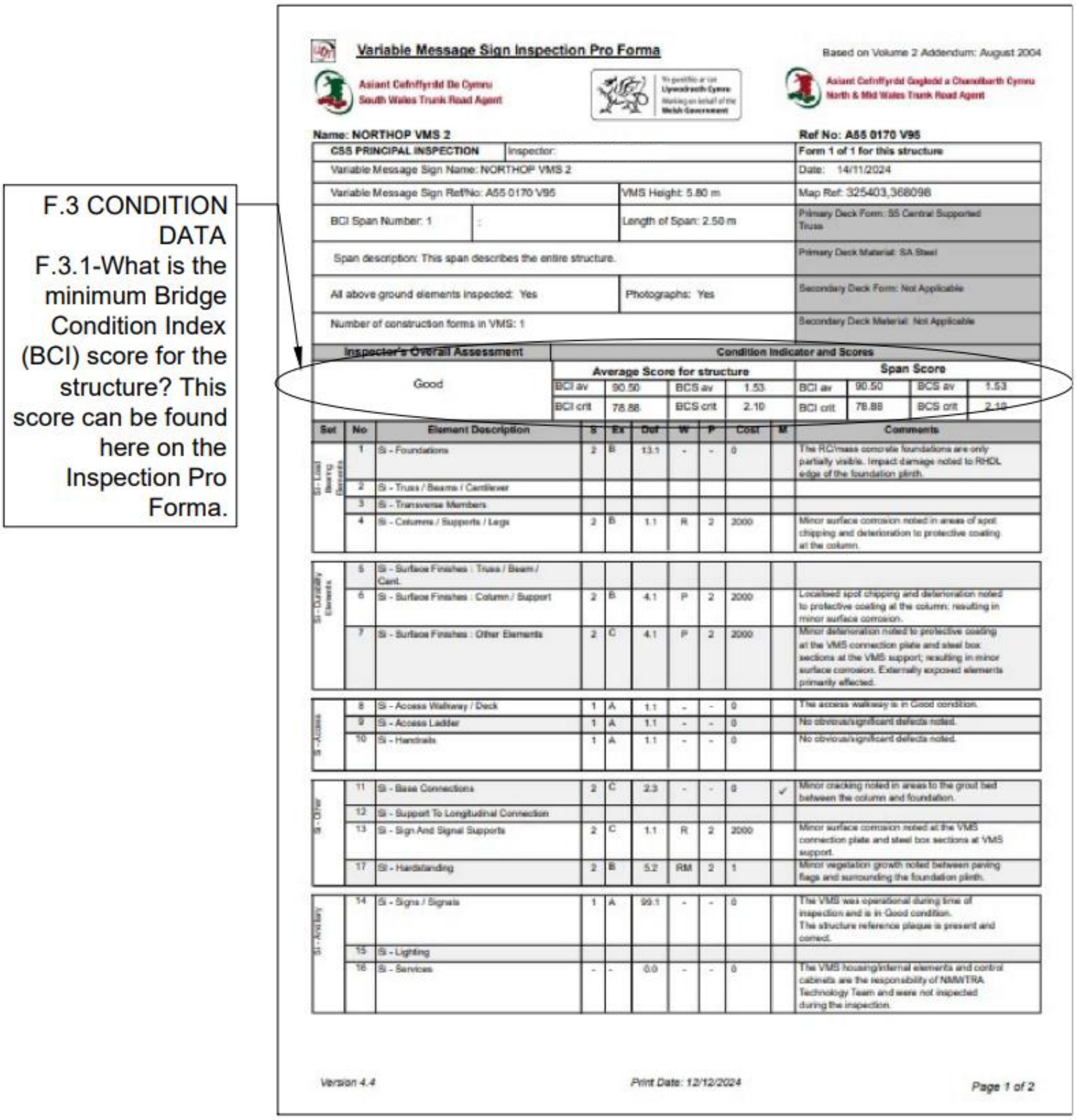
	Manufacturer	Type
Prestressing System		
Paint System: Parapet		
Internal		
External		

	Manufacturer	Type	Position
Bearings*	N/A	-	-
Joints*	N/A	-	-
Parapets	N/A	-	-
Waterproofing	N/A	-	-

*Indicate on sketch above

Figure 9 Using the Form Roads 277 to risk assess technology structures (2 of 2)

11.1.6. Using the Inspection Pro Forma – Technology Structures



Variable Message Sign Inspection Pro Forma

Based on Volume 2 Addendum: August 2004

Asiant Cefnffyrdd De Cymru
South Wales Trunk Road Agent

Asiant Cefnffyrdd Gogledd a Chanolbarth Cymru
North & Mid Wales Trunk Road Agent

Name: NORTHOP VMS 2

Ref No: A55 0170 V95

CSS PRINCIPAL INSPECTION	Inspector:		**Form 1 of 1 for this structure**
Variable Message Sign Name: NORTHOP VMS 2			Date: 14/11/2024
Variable Message Sign Ref/No: A55 0170 V95		VMS Height: 5.80 m	Map Ref: 325403,368098
BCI Span Number: 1	:	Length of Span: 2.50 m	Primary Deck Form: 55 Central Supported Truss
Span description: This span describes the entire structure.			Primary Deck Material: SA Steel
All above ground elements inspected: Yes		Photographs: Yes	Secondary Deck Form: Not Applicable
Number of construction forms in VMS: 1			Secondary Deck Material: Not Applicable

Inspector's Overall Assessment	Condition Indicator and Scores							
	Average Score for structure				Span Score			
Good	BCI av	90.50	BCS av	1.53	BCI av	90.50	BCS av	1.53
	BCI crit	78.88	BCS crit	2.10	BCI crit	78.88	BCS crit	2.10

Set	No	Element Description	S	Ex	Def	W	P	Cost	M	Comments
SI - Load Bearing Elements	1	SI - Foundations	2	B	13.1	-	-	0		The RC/mass concrete foundations are only partially visible. Impact damage noted to RHDL edge of the foundation plinth.
	2	SI - Truss / Beams / Cantilever								
	3	SI - Transverse Members								
	4	SI - Columns / Supports / Legs	2	B	1.1	R	2	2000		Minor surface corrosion noted in areas of spot chipping and deterioration to protective coating at the column.
SI - Durability Elements	5	SI - Surface Finishes : Truss / Beam / Cant.								
	6	SI - Surface Finishes : Column / Support	2	B	4.1	P	2	2000		Localised spot chipping and deterioration noted to protective coating at the column; resulting in minor surface corrosion.
	7	SI - Surface Finishes : Other Elements	2	C	4.1	P	2	2000		Minor deterioration noted to protective coating at the VMS connection plate and steel box sections at the VMS support; resulting in minor surface corrosion. Externally exposed elements primarily effected.
SI - Access	8	SI - Access Walkway / Deck	1	A	1.1	-	-	0		The access walkway is in Good condition.
	9	SI - Access Ladder	1	A	1.1	-	-	0		No obvious/significant defects noted.
	10	SI - Handrails	1	A	1.1	-	-	0		No obvious/significant defects noted.
SI - Other	11	SI - Base Connections	2	C	2.3	-	-	0	✓	Minor cracking noted in areas to the grout bed between the column and foundation.
	12	SI - Support To Longitudinal Connection								
	13	SI - Sign And Signal Supports	2	C	1.1	R	2	2000		Minor surface corrosion noted at the VMS connection plate and steel box sections at VMS support.
	17	SI - Hardstanding	2	B	5.2	RM	2	1		Minor vegetation growth noted between paving flags and surrounding the foundation plinth.
SI - Ancillary	14	SI - Signs / Signals	1	A	99.1	-	-	0		The VMS was operational during time of inspection and is in Good condition. The structure reference plaque is present and correct.
	15	SI - Lighting								
	16	SI - Services	-	-	0.0	-	-	0		The VMS housing/internal elements and control cabinets are the responsibility of NMWTRA Technology Team and were not inspected during the inspection.

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Figure 10 Using the Inspection Pro-Forma to risk assess technology structures

Appendix A – Development of the PIIRA Scoring System

Trials previously undertaken by Atkins on a group of 75 structures in South Wales found that the aggregate scores from the risk assessment could be categorised. The assessment included structures on the M4, A470 and A465 which were assessed independently by two teams and the results compared. Cross-referencing the risk assessment with engineering experience and knowledge, resulted in the classifications as shown in Table 19 below:

Accumulated Score	Recommended Principal Inspection Time Interval
x < 20%	Maintain at 6 years
20% ≤ x < 40%	Consider increasing to 8 years
40% ≤ x < 60%	Consider increasing to 10 years
x ≥ 60%	Consider increasing to 12 years (maximum)

Table 19 - Scoring Guidelines for risk assessment

Table 19 indicates that any structure scoring 20% or less as a result of the risk assessment process should have its Principal Inspection interval kept at six years. What this percentage score means is that from all of the positive attributes deemed achievable by any given structural type, the structure being assessed has that percentage proportion of them. For example, a structure scoring 100% has all the positive attributes available (according to the risk assessment) to that type of structure. Conversely, a structure with a 0% score has none of the positive attributes deemed achievable by the risk assessment.

Between 0% and 100%, there is clearly an upwards trajectory in terms of the decline in risk associated to the structures (i.e. 0% or lower representing higher risk structures and 100% representing lower risk structures). Evidence gathered during the trial of the risk assessment found that any structure scoring between 20% and 40% should be considered for an interval of eight years. Any structure scoring between 40% and 60% or 60% and above should be considered for an interval of 10 years and the maximum 12 years, respectively.

In comparison, a structure would require a Principal Inspection at a six-year interval if the requirements of CS 450 were implemented with no risk assessment, even if it was in a very poor condition with known load restrictions. The most appropriate way of dealing with this scenario is not to reduce the Principal Inspection interval but to either undertake a targeted Special Inspection of specific areas of the structure or to carry out emergency maintenance works to mitigate the risk.

Appendix B – Scoring Risk

Quantifying Risk – Likelihood

Quantifying the likelihood of deterioration and its consequences requires numerous criteria to be assessed each influencing the eventual outcome. When analysing the likelihood of deterioration for a given structure, and how rapid it may be, the criteria to be looked at are:

- Exposure severity – the structure may be subject to mild, moderate or severe exposure conditions. Varying external influences may cause rapid deterioration or failure. However, if a structure has always been exposed to these conditions, then it's likely that it will have been designed for such exposure and so contributes neither a positive nor a negative influence on the risk assessment. What will negatively influence the risk assessment is if evidence exists of a structure being exposed to conditions that it may not have been originally designed for or a structure not performing as expected or required. For example, a significant change in use above, adjacent to or beneath, a bridge may create destructive conditions detrimental to its long-term durability. Other examples include the obvious over-loading of a structure, exceeding assessed load limits and restrictions.
- Current condition – deducing an overall picture of the structure's condition should be achievable using the Inspection Pro-Forma from a recent General Inspection. As well as giving an assessment of its condition, this form should also detail specific defects to the main structural elements. Having such information is a key facet of assessing the likelihood of any, or further, deterioration.
- Level of contamination – symptoms of alkali-silica reaction (ASR), alkali-carbonate reaction (ACR), thaumasite-sulphate attack (TSA) or any other form of concrete degradation will constitute major influencing factors when evaluating the likelihood of deterioration. Identifying whether a structure is predisposed to concrete attack is difficult and this risk assessment does not attempt to do so. Other related factors, like age, can, however, be taken into account.
- Age - when evaluating the likelihood of deterioration, age plays a significant part. Relatively new structures can have numerous unknowns, including the potential for concrete attack to initiate (see above) and unexpected design deficiencies. Similarly, old structures nearing their design life also have a number of obvious, age-related problems. The risk assessment, therefore, takes the view that very old structures and very new structures represent the highest risk. For the purpose of this risk assessment, a structure of an age between being 5% and 70% of its design life is seen as being least likely to deteriorate unexpectedly. Any structure of an age under 5% of its design life or over 70% of its design life is seen as being most likely to deteriorate unexpectedly.
- Material type – the materials used for construction influence how confidently one can assess the likelihood of deterioration. This is based on an historical understanding of material properties, both positive and negative. For example, reinforced concrete has a proven track record in bridge construction for more than 100 years and is known to be a durable material with longevity. Post-tensioned concrete, however, has had historical problems, particularly when present in some structural forms (i.e. segmental beam construction).
- Structural form – the form, whether it is an arch, a simply-supported slab or an integral bridge, often determines the extent to which local deterioration will affect the structure as a whole. For example, a slab or arch will undergo progressive, slow deterioration. A beam structure with independent members may be at higher risk of rapid deterioration because a localised problem with one beam may compromise the integrity of the structure as a whole. Whether the extent of any deterioration is local or global should also be considered.

- Historical rates of deterioration - for any observed deterioration ‘mechanism’, some defects are known to take many years to develop to the point where they require maintenance or present a risk to structural integrity and public safety. The maintenance (or, perhaps, even strengthening) history of the structure should be taken into consideration and structure-specific characteristics such as fatigue-prone details and susceptibility to scour damage should be considered.
- Severity and extent of damage due to incidents – the potential for vehicular impact, scour (particularly following flooding) and vandalism, and whether this is likely to lead to further deterioration before it can be repaired should be considered.
- Potential modes of failure – materials, structural forms or loading conditions that could lead to a brittle or ductile failure should be considered, as well as understanding the degree of redundancy present for each structure. Additionally, failures likely to be progressive following long-term deflection and crack propagation should also be considered.
- Loading – it’s possible for any bridge to experience loads higher than those they were designed for. However, those bridges which have load restrictions in place are more likely to be overloaded since this can occur due to a larger number of vehicles.

Quantifying Risk – Consequence

The second part of assessing risk involves a consideration of the consequences of deterioration or failure. For example, deterioration may be likely but if the structure being assessed is a disused culvert remote from the carriageway, the consequence of failure is minor. The other extreme is a multi-span motorway bridge, with a low likelihood of deterioration but having potentially catastrophic consequences, if unexpected deterioration were to occur. Quantifying consequence, therefore, comprises a less technical, but also less ‘clear-cut’ set of criteria than ‘likelihood’. There are two differing types of consequence, with the first looking at deterioration local and insular to the structure, whilst the second looks at the wider implications of potential failure. It is certainly not as straightforward as looking at location and usage of the structure, and then assuming what the consequences will be. A more complex blend of political, social, economic, technological, legal, and environmental impacts can exist.

- ‘Localised’ consequence – analysing the localised consequences of deterioration needs a consideration of the potential failure modes associated with a structure, and the degrees of redundancy available. Where deterioration affects a deck comprising a number of individual members, for example, collapse can be instigated from weakness in one part of one member. The consequence of deterioration is, therefore, high. Conversely, for a continuous slab deck, collapse will require multiple progressive failures to occur. In this case, deterioration (e.g. cracking) will be identified at biennial General Inspection stage, giving enough time for adequate management processes to be instigated. Comparing the two cases, the consequence of leaving deterioration is much higher on a simply supported beam structure than on a continuous slab structure.
- Wider, ‘global’ consequences– with any structure, a number of stakeholders will exist, each with different expectations and different opinions on the structure’s importance. For example, deterioration of a bridge leading to an ‘out-of-town’ industrial estate may have little consequence to the structure’s owner, or even the public at large, but failure may have major repercussions for those businesses, and wider stakeholders, that rely on it. Gauging consequence at a wider scale can be hugely subjective, and the owner of a structure can only measure its true strategic importance through years of experience and knowledge of its stakeholder impact. It cannot be determined quickly through a risk assessment, reliant on basic data from the Inspection Pro-Forma and Form Roads 277s.

Though never explicitly referred to by the risk assessment, the consequence of deterioration is implicit throughout. In spite of likelihood and consequence of being, in theory, two distinct parts of the 'risk equation', they are, more often than not, interlinked. For example, a structure subjected to vehicular loading is more likely to deteriorate than if that structure was not subjected to those loads. And, clearly, the consequence of failure is much higher when a structure is subjected to vehicular loads. Those attributes a structure has that make deterioration more likely, are also, frequently, the same factors that make the consequence of failure so much greater. Likelihood and consequence are not mutually exclusive of each other, then. This is particularly true when analysing risk at a local level (e.g. failure mode effect analysis), and for that reason, it is much easier to quantify, or measure, consequence at smaller scales. As the scale increases, so does the complexity and the level to which a computerised risk assessment like this can inform judgement reduces considerably. This risk assessment does not quantify the wider logistical, socio-economic impact of a structure failing, or needing to be closed. It gives a measurement of the risk, based on basic structural facts (e.g. Inspection Pro-forma and Form Roads 277), taking the structure in isolation. It analyses consequence, but only up to a point. Gauging the wider importance of a structure is, and always should be, the domain of experienced engineers making measured decisions. For example, this risk assessment could classify a bridge as low risk, finding deterioration unlikely and the localised consequence of that deterioration to be minimal. Yet when the location of the bridge (e.g. if it carries the most heavily trafficked sections of the M4 or A55) gives that bridge huge strategic importance to the region, the consequences of failure become significantly higher. Taking a wide-ranging, holistic view of those factors affecting a structure is vitally important. Though this risk assessment can assist in forming that overall picture, it should not be left as a stand-alone source.

Weighting Scores

Each risk assessment/questionnaire is divided into four main categories of question. These cover the four main categories of structural attributes which most heavily influence the likelihood for deterioration, and the consequence of failure. There are **Historical** questions, **Inspection** questions, **Condition** questions and **Usage** questions.

Each category of questions has different levels of importance and are weighted in such order. The greater the influence the category has on the risk assessment, the greater the weighting it is given. The weightings of all four categories add up to 100 (i.e. the percentage total). For example, a culvert being risk assessed will be weighted as follows:

- **Historical** score – W = 25%
- **Inspection** score – W = 25%
- **Condition** score – W = 30%
- **Usage** score – W = 20%

In this case, points accumulated under Condition questions are given greater influence in the overall risk assessment than those accumulated for Historical, Inspection data and Usage questions. There will be appropriate variations of these weightings based on other structural types.